The consumption of energy in developed countries is very high as compared to developing countries. It is the need to use of energy very carefully for getting highest yield in agricultural production system. Sugarcane is an important commercial crop and it cultivated in about 75 countries. The leading countries are Brazil, India, China, Thailand and Pakistan in the production of sugarcane. Sugarcane belongs to the bamboo family of plants and is indigenous to India. It is the main source of sugar, gur and khandsari. About two thirds of the total sugarcane produced in India is consumed for making gur and khandsari and only one-third of it goes to sugar factories.

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Energetics of Sugarcane

Analysis of Energy

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Avinash Kumar

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LIST OF SYMBOLS AND ABBREVIATION

AICRP	-	All India Coordinated Research Project
Avg.	-	Average
CAE	-	College of Agricultural Engineering
e.g.	-	Exempli Gratia (For Example)
et al.	-	And Others
etc.	-	Etcetera (and so on)
Fig.	-	Figure
FYM	-	Farm Yard Manure
GJ	-	Giga Jules
ha	-	Hectare
hp	-	Horse Power
h	-	Hour
i.e.	-	id est (that is)
J	-	Jules
JNKVV	-	Jawaharlal Nehru Krishi Vishwa Vidyalaya
Kg	-	Kilogram
KWh	-	Kilowatt hour
lit.	-	Litre (s)
M-hr	-	Man hour
Max.	-	Maximum
MF	-	Marginal Farmer
Min	-	Minute
MJ	-	Mega jules
M.P.	-	Madhya Pradesh
SF	-	Small Size Farmer
TJ	-	Tera Jules
Viz.	-	Such as

INTRODUCTION

Energy plays a major role in national development process and in providing major vital service that improve human condition – fuel for cooking, light for living, and motive power for transport and electricity for modern communication. In agricultural sector energy is used in every form of inputs – human and animal power, seed, fertilizer, agro chemical for plant protection, machinery use for various operations being operated by electricity and fossil fuels, biomass and coal for living, and is directly linked with technological process.

Agricultural production can be increased, by bringing additional land area under cultivation, and by increasing the cropping intensity. Productivity can be increased by increasing the production per unit area of land, which in turn also increases the total production. In India, there is little additional land available for agriculture. The increase in cropping intensity require additional supply of energy for irrigation as well as for timely tillage and harvesting. Increase in productivity also requires additional mechanical power. Substantial increase in the yields of important cereals and coarse grains were made possible by the introduction of high yielding varieties and increase of area under irrigation. But this success was achieved mainly with the help of fertilizers and wider utilization of mechanical and electrical power in farming, particularly in Punjab, Haryana and Western U.P. (Baiyegunhi and Arnold. 2011).

The availability of power on the farms in India has to be increased, if productivity is to be raised. More power is needed for timely and quality tillage, as well as for irrigation, harvesting and threshing. Quantification of energy panorama, involve scientific surveys of various input energy forms, and this may be termed as ‘Energy Audit’. Power energy audit would provide better understanding of changes in energy consumption patterns and would become a measure of technological progress in energy utilization efficiency. It will also provide better guidelines for inter and intra system allocation of energy resources. The projects which constitutes the subject matter of this thesis, and the results of which are given at the end, were taken up, with a view to collect and collate all available information about energy consumption in Madhya Pradesh agriculture, and suggest tentative guidelines for future workers, on energy scene in this State (Khandelwal and Raghuvanshi.1985).

The state of Madhya Pradesh is situated in the heart of India between latitude 21 degree to 26-degree N and longitude 74 degree and 81-degree E. The mean temperature varies from less than 10 degrees Celsius to more than 46 degrees Celsius during winter and summer respectively. The annual rainfall varies from below 800mm in the western part of the state, to be above 1600mm in the eastern region (Khandelwal et al. 1993).

The estimated population of the state is 79.9-millions with a density of 236 persons per sq. km. There is a variety of soil type ranging from lateritic through mixed red and black-to-black soils of different depths. The net-cropped area of the state is 19.89 million hectares, of which only 5.6-million-hectare land is irrigated. The cropping intensity of the state is 132 per cent, which is below national average of 135 per cent (Khandelwal et al. 1993).

The energy requirements in various facets of agriculture (including livestock production and household's activities) vary considerable due to variations in the technology level adopted by the farmers and also because of the diverse agro-climatic conditions. Technology level and agro-climatic conditions constitute the most important factors pertinent in the production of a crop in the state of Madhya Pradesh. Agriculture is the main source of income of the majority of the population of the state (Khandelwal and Raghuvanshi.1985).

Sugarcane ***(Saccharum officinarum L.)*** an old energy source for human beings and more recently, a replacement of fossil fuel for motor vehicles was first grown in South East Asia. It was introduced to Egypt around 647 A.D. and about one century later to Spain (755 A.D.). It is an important crop in the Indian sub-continent (Anonymous, 2009).

Sugarcane production is expected to be lower at 309 million tonnes (2016-17), compared to 348 million tonnes the year before. Production of cotton is set to increase from 30 million bales last year to 32.5 million bales in 2016-17 (one bale equals 170 kg). However, this is lower than the past record of 35.9 million bales produced in 2013-14 (Anonymous, 2017).

1.1 Major Sugarcane Growing States

Sugarcane is grown in various states in subtropical and tropical regions of the country. Main sugarcane growing States are:

1.1.1 Sub Tropical: Uttar Pradesh, Uttarakhand, Haryana, Punjab, Bihar with an annual rainfall of 180 to 2000 mm. The climate ranges from humid, moist sub-humid and dry sub-humid to cold arid, semiarid and arid.

1.1.2 Tropical region: Karnataka, Tamil Nadu, Maharashtra, Andhra Pradesh, Gujarat, Madhya Pradesh with an annual rainfall of 602 to 3640 mm having moist to dry sub- humid and semi-arid to dry semi-arid climates (Singh et al. 2015).

1.2 Important regions/ zones for sugarcane cultivation in India

Broadly there are two distinct agro-climatic regions of sugarcane cultivation in India, viz., tropical and subtropical. Tropical region shared about 45% and 55% of the total sugarcane area and production in the country, respectively. Sub-tropical region accounted for about 55% and 45% of total area and production of sugarcane, respectively.

1.2.1 Tropical Sugarcane region

The tropical sugarcane region includes the states of Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Madhya Pradesh, Goa, Pondicherry and Kerala. The coastal areas of A.P. and Tamil Nadu have high sugarcane productivity. Floods, water logging and diseases such as red rot are the main problems. In the tropical region climatic conditions are more favourable for its growth. It is cultivated with better package of practices and higher irrigation levels. The growing season is long with more equitable and favourable conditions without serious weather extremes. Being a tropical country the agro-climatic conditions of tropical India favour higher sugarcane and sugar yields. The tropical region contributes about 55 per cent to the total cane production in the country. The average cane yields of the major states of the region including Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh and Gujarat is around 80 tonnes per hectare. Maharashtra and the adjoining area of Karnataka, Gujarat and A.P. record higher sugar recovery. Long hours of sunshine, cool nights with clear skies and the latitudinal position of this area

are highly favourable for sugar accumulation. Moisture stress during the early part of the cane growths mostly during March to June is a major constraint in the state of Maharashtra & other part of region lacking perennial source of irrigation (Singh et al. 2015).

1.2.2 Sub-tropical sugarcane region

Around 55 per cent of total cane area in the country is in the sub-tropics. U.P, Bihar, Haryana and Punjab comes under this region. Extremes of climate are the characteristic feature of this region. During April to June, the weather is very hot and dry. July to October is rainy season accounting for most of the rainfall from South-West monsoon rains. December and January are the very cold months temperature touching sub-zero levels in many places. November to March are cool months with clear sky. The cane yield is lower in the subtropics due to various reasons viz., short growing season, high temperature disparity besides other factors like moisture stress, pest and disease problem, floods and water logging and very poor ratoons. The average yield of the four major states (U.P, Bihar, Punjab and Haryana) is around 60 tonnes per hectare. However, there is considerable potential to be exploited (Singh et al. 2015).

At global level, total 121 countries are producing the sugarcane. Out of them some of important countries like Brazil, India, China, Thailand, Pakistan, Mexico, Cuba, Columbia, Australia, USA, Philippines, South Africa, Argentina, Myanmar and Bangladesh are producing approximately 80% of total world production of sugarcane. Worldwide, sugarcane occupies an area of 20.42 million hectare with a total production of 1333 million metric tonnes. Sugarcane area and productivity differ widely from country to country. Brazil has the highest area i.e. 5.343 million hectare, while Australia has the highest productivity i.e. 85.1 tonnes/ha (Anonymous, 2009).

In India, the total area under sugarcane cultivation was reported to be about 49.18 lac hectare. The country produced about 3414.25 lac tonnes of cane at a national average of about 69.42 tonnes/ha in the year of 2015-16 (FAO, 2015). India occupies the second rank in production of sugarcane in the world and contributes nearly 20.4% area and 18.60% production. The major sugarcane growing states are Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka and Madhya Pradesh etc. The

area and production of sugarcane in Madhya Pradesh is about 0.73 lac hectare and 31.73 lac tonnes (FAO, 2015).

The energy consumption in production of sugarcane is highest as compared to many other crops such as potato, maize, wheat, rice, sorghum etc. Sugarcane is labour intensive requiring about 3300 man-hrs per hectare for different operations. Considering the present trend of availability of labour for sugarcane production, it has been experienced that the use of modern machinery is inevitable. Use of machinery helps in labour saving and timelines of operations, reduces drudgery, helps in improving quality of work, reduces cost of operation and ensures effective utilization of resources (Naeem et al. 2007 and Singh et al. 2015).

Table-1.1 All India state wise area coverage and yield estimate of sugarcane during 2013-2016

Name of state	2013-14			2014-15			2015-16		
	Area (000ha)	produ-ction (000 t)	Yield (t/ha)	Area (000ha)	produ-ction (000 t)	Yield (t/ha)	Area (000ha)	produ-ction (000t)	Yield (t/ha)
Madhya Pradesh	73	3173	43.47	111	4567	41.14	73	3343	45.79
Andhra Pradesh	192	15385	80.13	177	13150	74.29	157	12460	79.36
Tamil Nadu	313	32454	103.69	263	24463	93.02	263	27615	105.0
Gujrat	174	12550	72.13	204	14060	68.92	185	13040	70.49
Punjab	89	6675	75.00	94	7039	74.88	99	7131	72.03
Uttar Pradesh	2228	134689	60.45	2228	138481	62.15	2116	133203	62.95
India	4993	352141	70.53	5144	359330	69.85	4918	341425	69.42

Source: Indian institute of sugarcane research institute Lucknow/database

The energy consumption in production of sugarcane is highest as compared to many other crops such as potato, maize, wheat, paddy, sorghum etc. Sugarcane is labour intensive requiring about 3300 man-hrs per hectare for different operations.

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Keeping in view the above, it was tell that, there is a need to study energy use pattern and change in its scenario. Therefore, the study was carried out for sugarcane (ratoon) crop in Narsinghpur region of Madhya Pradesh with the following objectives:

OBJECTIVES

1. To assess energy use pattern in different operations from various sources for cultivation of sugarcane in the district of Narsinghpur, Madhya Pradesh.
2. To assess the power availability use pattern in sugarcane cultivation in the district of Narsinghpur, Madhya Pradesh.
3. To project the energy demand for mechanization of sugarcane cultivation for future in the district of Narsinghpur, Madhya Pradesh.

REVIEW OF LITRATURE

Energy is a basic requirement for human life, agriculture, industry, transportation, consumption and all other economic activities of the present civilization. So far as India is concerned, agriculture constitutes the foundation of socio- economic structure. 70 % of population is engaged in activities related to crop, animal, aqua production, processing and marketing.

The sun is the primary source of energy. Other forms of energy such as green plants, animals, human beings, coal tar, water, wind and tidal energy are directly or indirectly dependent on solar energy. Crop plants convert solar energy into plant body building substances through photosynthesis.

The scientists working on assessment of energy requirement in agricultural sector have continuously been monitoring and investigating use of energy inputs for increased productivity. Their findings are documented in various research journals. These findings can be classified in to following main headings:

- Energy – The global concern.
- Energy Use Pattern in Indian Agriculture.
- Crop wise and source wise energy use pattern.
- Economics of energy use on farms.
- Changing trend of energy use.

2.1 Energy – The global concern

Kishida (1969) reported that in the developing countries including those in Asia, power available per hectare was less than minimum required hp range. The average yield of main crops was also stated to be low. According to him the minimum necessary hp per hectare for obtaining proper production was between 0.5 and 0.8 per hectare in the developing countries. Under Indian conditions, his estimation of power requirement was in the order of 0.8 hp per hectare for reasonably satisfactory agricultural production. As against this, the available power was only 0.32 hp per hectare. About 75 % of this power was again supplied mainly by animals the present estimate being that 80 million draft animals and 144 million effectives human labour were engaged in agriculture in India.

Donal and Gordon (1976) stated that agriculture was both a user and a producer of energy. A subsistence farmer uses the energy of his family and his draft

animals to grow crops and crop growth also depends on the process of photosynthesis, which converts energy from the sun into vegetable matter (solar energy was the ultimate source for all man's traditional energy forms). The crops in turn produce energy in the form of food calories.

Goswami (1976) determined the energy requirement for lift irrigation in tarai area of North Bihar. He stated that the energy requirement for rabi crops was much higher than the kharif crops. The diesel consumption per acre for full irrigation was 27.59 litres giving the energy output at the rate of 0.39 litre per hp per hr. An average farm utilized energy worth 969 hp hr for irrigation during the year. The energy requirement may go high up to 2.629 hp hr if the entire cropped area of an average farm was brought under irrigation subject to existing pattern of cropping and energy input.

Maheshwari (1981) reported energy census of village Islamnagar (Bhopal District). Activity wise total energy consumption was found to be 14.9per cent for crop production, 0.5 per cent for post harvest operation, 0.8 per cent for cattle raising and 83.8per cent for domestic activities. The sources of energy were 80.7 per cent ,17 per cent. and 2.3 per cent for commercial and non- commercial. Whereas, the average energy consumption of crop production was found to be 9459 MJ/ha/yr.

Zentner et al. (1984) conducted that the study to examine energy inputs, output and efficiency of 12 crops rotation in brown soil zone of the prairie provinces. The main objective of this study was to evaluate the influence of rotation length, selected summer fallow substitute crops, and N and P fertilizer on crop yield, grain protein, N and P uptake by the plants and changes in soil chemical, physical and biological properties. Results revealed that total energy input per unit area was lowest for the traditional 2 yr fallow – wheat rotation, intermediate for the 3 yr fallow wheat – wheat rotation and highest for the continuous wheat rotation. Energy output generally increased with decreasing the fallow length in crop rotation because of the greater quantity of annual grain production per unit area.

Singh et al. (2000) found different mathematical functional relations between yield and total energy input. An attempt was also made to optimize the energy inputs using frontier production function (unconstraint and constraint frontier functions). The energy input through fertilizer was almost 12-15 percent more when used the recommended dose for paddy on all farm categories. Use of total energy input

beyond 29000MJ/ha decreased the yield of paddy. The yield of paddy can be increased by 3-4 percent with an additional energy input 15-17 percent mainly through tillage, irrigation and fertilizer. There was a scope of increasing yield by 9-10 percent with the additional energy input of 1-2 percent on semi-medium farms.

Ozkan et al. (2004) carried out a study on energy use in the Turkish agricultural sector for calculation of energy use in agriculture, included both human and animal labour. They included machinery, electricity, diesel oil, fertilizers, seeds and 36 agricultural commodities to get output for the period of 1975 – 2000. They found that the total energy input increased from 17.4 GJ/ha in 1975 to 47.4 GJ/ha in the year 2000. Similarly, total output energy increased from 38.8 to 55.8 GJ/ha in the same period. The output input ratio was estimated to be 2.23 in 1975 and 1.18 in 2000.

2.2 Energy Use Pattern in Indian Agriculture

Rautray and Das (1983) studied the energy inputs on various farm operations in production of sorghum and gram as mixed farming in black soil at CIAE, Bhopal. The results showed that the bullocks system with the combination of improved implements required the lowest direct energy input per unit yield of sorghum (3.48 kWh/q) and gram (8.00 kWh/q) as compared to system using bullocks with conventional implements and the energy use in both the systems differed significantly.

Choudhary (1985) studied the impact of farm technology and energy use in agriculture of developing countries. The low farm productivity in developing agriculture was the result of increasing pressure on farmers to produce more by intensifying tillage, which continuously degraded soil. An alternative farming system “conservation tillage” is needed to exploit the potential of this proven technology.

Khandelwal and Raghuwanshi (1985) reported, 8 per cent saving in human energy, 9 per cent in animal energy and 60per cent of farmyard manure energy is feasible, other energy resources requirement being as that presently used by the farmers. Sowing energy can be saved by 15per cent through shift to tractor seed drill, harvesting energy by 34 per cent and threshing energy by 13 per cent through efficient use of threshers. Additional 2.2 per cent energy is to be invested for proper irrigation. Although energy use in seedbed preparation would remain same, the

combination of tillage equipment uses would reorient with shift to tractor operated cultivator. Use of animal operated tillage equipment would reduce by 33 per cent. Energy productivity would improve 0.205 to 0.270 kg/MJ in mix farm.

Singh et al. (1985) reviewed the work done on energy consumption pattern in crop production. They stated that energy consumption in Indian agriculture has been steadily increasing from 1953-54 onwards recording a quantum jump between 1965-66 and 1975-76. However, energy use efficiency of Indian agricultural systems has consistently been declining from 5.5 in 1961 to 3.4 in 1984 this call at least for maintenance at the latter level. In fact, modernization of agriculture has enhanced is dependence on non- renewable energy sources.

Mishra (1986) made energy analysis of major crops of Tarai region of Utter Pradesh by considering different sources of energy and operations in crop production. Irrigation, seed bed preparation and threshing consumed 70-88 percent of the total energy in wheat crop production. Energy could be saved by using improved implements whether it was tractor drawn or bullock drawn. Yield increased with increased energy consumption.

Dhawan and Mittal (1990) compiled the data of various research works of India to study energy use pattern for paddy and wheat production. They found that in nineties animate power source contributed most of the energy use in crop production. High yielding varieties of major crops required higher inputs in the form of fertilizers, irrigation, diesel fuel, chemicals and electricity. Water supply was found to be most critical factor in the use of energy for crop production in irrigated areas using intense fertilizers.

Singh et al. (2002) analyzed energy use pattern in country and found that the commercial energy use in agriculture increased nearly six-fold with growth rate of 11.8per cent between 1980-81 to 2000, but the share of agriculture in total energy consumption in the country increased 2.3 to 5.2per cent during the same period. About 57per cent of the Indian populations depend upon agriculture.

Singh et al. (2003) conducted that a study on energy use pattern in production agriculture of a typical village in arid zone of India. They reported that the maximum energy was required for raising cotton, followed by wheat, mustard, maize and cluster bean crops. There was more non - renewable form of energy input (73.2%) than renewable form (26%) in all crops. The energy ratio varied from 3.4 to 7.0

suggesting that the cultivation of the cotton crop having an energy ratio 7.0, was more profitable compared to other crops.

Raju et al. (2015) studied the technological change in agriculture had made significant impacts on labour absorption, notably since green revolution. In this context the present study analyses the pattern and trend in labour absorption across major states and crops during the period of mid-1970s to 2010. The entire period of analysis has been sub-divided into two, up to mid-90s as first period and post-mid 90s till 2010 as the second period, broadly corresponding to the period of green revolution and market reforms, respectively. The analysis was carried out for rice and wheat, two major food crops cotton and sugarcane, two major commercial crops. The results indicated that at national level, there was wide variation in the trend in labour absorption among the four crops under study: while a continuous decline has been observed in the case of wheat during the entire period, it has been continuously rising in the case of cotton. On the other hand, paddy and sugarcane depicted varying trends over the time- increasing labour absorption up to mid-1990s, but declining thereafter. This trend at national level corresponds to the spread of technological changes in agriculture.

There was wide variation in the composition of human labour and machine labour use. The share of human labour in total cost of cultivation registered significant increase between TE 1975-76 and TE 1995-96 in most cases and a mixed picture emerged thereafter. Among the states, the highest share of human labour in total cost of cultivation of paddy was observed in Assam and West Bengal at about 42% each, whereas it was the lowest in Punjab at about 18 per cent.

Singh et al. (2015) stated that the production and productivity were directly related with use in unit operation of agricultural production. The variation in yield of crop occurs in India due to wide variation in energy inputs, agro-climatic conditions and resources used. Keeping this in view, a study had been carried out to find the energy scenario of sugarcane (ratoon) crop for sugarcane production in Bhabar region of Uttarakhand, India. The scenario shows, energy consumption was highest in tractor farm followed by animal farm and mixed farm in this region and total operational energy ranged from 3576 to 6222 MJ/ha for sugarcane (ratoon) crop cultivation. Irrigation was the highest energy consuming operation in sugarcane

(ratoon) crop cultivation operations. The energy productivity ranged from 2.712 to 3.944 kg/MJ for sugarcane (ratoon) crop cultivation.

2.3 Crop wise and source wise energy use pattern

Borker (1973) investigated on soil requirement and energy requirement for wheat crop when grown on lateritic clay loam soil. He also measured the effectiveness and suitability of tillage implement for some selected of operations. Form the results he observed that maximum grain yield occurred when the soil mean weight diameter, which is an index for measuring the soil tilth, is within 11 to 13 mm. For the seed bed preparation with a mould board plough, followed by a disc harrow, the total energy requirement was respectively 183.75 Kw-h/ha, 201.91Kw-h/ ha for moisture contents of 12.57 % 8.93% and 16.74% respectively. He also found that energy requirement was higher in the case of mould board plough than rotary tiller and cultivator.

Adil et al. (1992) carried out study concerned with the energy output for wheat and cotton and energy consumption pattern by farm size in Pakistan. The study reflected a positive relationship between farm size and energy use levels as well as between the energy level and the output of wheat. Pakistan consumed energy at a level almost 50 percent of the average energy consumption in developing countries. The input of energy is a factor to influence productivity. Energy derived from a number of sources, but oil and gas occupy dominant positions. Small farmers derived more energy from the animate source, whereas large farmers used more commercial energy.

Singh and Singh (1992) conducted survey in Meerut district of Northern India Data was collected from 500 crop plots from 24 farmers of 6 villages. Mathematical relationship between energy inputs and crop yields of wheat, sugarcane and maize were developed. For all three crops, yield seemed to be linearly correlated with total energy input. Wheat and maize yield showed significant linear correlation with pre-harvest energy input (field operations and fertilizer energy) while sugarcane yield was found related to field operations energy input only. Fertilizer energy input was found to affect wheat and maize yield more than irrigation energy while irrigation energy input was most influencing on sugarcane. In general crops yields did not show any direct relation with tillage energy.

Khandelwal et al. (1993) reported that for paddy cultivation the major energy consulting operation was tillage, which consumed 30-35 % of total operational energy. The output input energy ratio increased with the level of tillage. Large farm used more commercial energy and also received higher yield. Use of improved implements chemical weeding and increased fertilizer use was recommended.

The crop yield did not show any direct relationship with tillage energy for wheat in Punjab (Singh *et al.* 1994b). This study was carried out on crop yield and various energy inputs per unit-cultivated area such as tillage, irrigation, fertilizers and pre-harvest and total energy. Neldor's curve and Robb's parabolic expressed the relationship between irrigation energy and yield and also fertilizer energy and yield respectively. Similarly, relationship between pre-harvest energy and yield as well as total input energy and yield were both expressed with the quadratic function. The coefficient of determination was significant at the 1% level of significant and showed that the function could explain the effect of inputs on yield at high level of significant.

Sahabi et al. (2012) conducted that the efficient use of energy helps to achieve increased production and productivity and contributes to the economy, profitability, and competitiveness of agricultural sustainability of rural communities. Evaluation of wheat and barley production systems in view of energy balance was conducted in Khorasan Razavi Province, Iran. Data were collected by using a face-to-face questionnaire from wheat and barley fields in 2011. Results revealed that total energy input for wheat was 51,040 MJ/ha and for barley 44,866; in wheat and barley systems, renewable energy was consumed by 25.43 and 23.53 %, while non-renewable energy was consumed by 74.57 and 76.47 %, respectively. Energy use efficiency, energy productivity, and net energy were 1.7 kg/MJ, 0.088 kg/MJ, and 35,987 MJ/ha in wheat system and 1.83 kg/MJ, 0.092 kg/MJ, and 33,833 MJ/ha in barley system, respectively. Energy intensiveness in wheat fields (61.84 MJ $-1) was higher than in barley fields (58.71 MJ $-1). Also, benefit-to-cost ratio in wheat system (1.59) was higher than in barley system (1.35). In general, production in barley fields was more sustainable than wheat production because, in view of ecological indices such as amount of energy use and renewable energy consumption, it was more environment-friendly production.

Sajjad and Prasad (2014) stated that the dynamics of crop diversification in one of the agriculturally prosperous districts of Indian Punjab using Gibbs Martin

Index. Spatio-temporal analysis of crop diversification in the district shows decline in crop diversification in most of the blocks (administrative sub divisions). The cropping pattern in most of the blocks of the district had become over specialized in the favour of rice-wheat rotation. Net irrigated area was continuously increasing for the cultivation of rice and wheat in the study area. Declining diversity of crops in the district had serious repercussions for natural resources, ecology and socio-economic condition of the farmers.

Bastian and Shridar (2014) stated that the mechanisation of harvesting was crucial for ensuring cost effectiveness of sugarcane cultivation. De-trashing was the removal of leaves and top from harvested cane stalk. The operating parameters of a high-speed rotating brush type de-trashing mechanism were investigated so as to aid the development of a combine harvester.

Reddy et al. (2015) studied that in this study an attempt had been made to study the resource use efficiency of input factors of production of paddy, bajra, and groundnut. The unrestricted Cobb- Douglas production function had been utilized for the study. The data were collected with the help of from survey method through personal interviews from the farmers. The analysis shows the pattern of resource use need some modification, particularly, the application of HYV seeds and chemical fertilizers and pesticides should be increased in the case of paddy and Bajra whereas in the case of groundnut, the application of human- labour, irrigation, chemical fertilizers and pesticide to obtain more yield.

Jalalzadeh et al. (2016) carried out a system dynamic methodology used for estimating effects of mechanization level index on the mean yield of farm crop products, considering the main input and output of farming crops' production system of Iran. A collection of constant parameters, logical relations and statistically estimated functions which were effective in mechanized farm crops' production of Iran, defined as an autonomous system and time span for modelling was defined a period 70-year viz. 1981 up to 2051. Running the established model by simulation software, resulted in key parameters, needed for creating "The production function" as mean yield of farm crop products depended to mechanization level index. After testing validity of the created model, analyzing estimated production function resulted in recognizing three economic production regions. The first economic production region continued from 1.342 Kw/ha to 2.013 Kw/ha; The second

production region started at 2.013 Kw/ha and ended at 2.386 Kw/ha, and finally the third production region started from 2.386 Kw/ha for mechanization level Index, while the maximum profitable point for farm crops production appeared at 2.218 Kw/ha in simulation procedure. All the analysis based on the available statistics for agricultural sector of Iran, since 1981 up to the recent time.

2.4 Economics of energy use on farms

Duke and Kammen (1999) they evaluated three energy-sector market transformation programs: The Environmental Protection Agency's on-going Green Lights program to promote on-grid efficient lighting, the World Bank Group's new Photovoltaic Market Transformation Initiative, and the federal grain ethanol subsidy. They developed a benefit-cost model that uses experience curves to estimate unit cost reductions as a function of cumulative production. Accounting for dynamic feedback between the demand response and price reductions from production experience raises the benefit-cost ratio (BCR) of the first two programs substantially. The BCR of the ethanol program, however, it was approximately zero, illustrating a technology for which subsidization was not justified. Resulted the support a broader role for market transformation programs to commercialize new environmentally attractive technologies, but the ethanol experience suggests moderately funding a broad portfolio composed of technologies that meet strict selection criteria.

Abhyankar (2003) reported that the usage of energy resources in industry leads to environmental damages by polluting the atmosphere. The gross generation of power in the year 2002-03 stood at 531 billion kWh. The relationship between economic growth and increased energy demand was not always linear one under present condition 7 per cent growth in GDP would impose an increased demand of 11.5 per cent on its energy sector.

Drewnowski and Darmon (2005) they studied that highest rates of obesity and diabetes in the United States were found among the lower-income groups. The observed links between obesity and socioeconomic position may be related to dietary energy density and energy cost. Refined grains, added sugars, and added fats are among the lowest-cost sources of dietary energy. They were inexpensive, good tasting, and convenient. In contrast, the more nutrient-dense lean meats, fish, fresh vegetables, and fruit generally cost more. An inverse relationship between energy density of foods (kilojoules per gram) and their energy cost (dollars per mega

joule) means that the more energy-dense diets are associated with lower daily food consumption costs and may be an effective way to save money. However, economic decisions affecting food choice may have physiologic consequences. Laboratory studies suggest that energy-dense foods and energy-dense diets have a lower satiating power and may result in passive overeating and therefore weight gain. Epidemiologic analyses suggest that the low-cost energy dense diets also tend to be nutrient poor. If the rise in obesity rates were related to the growing price disparity between healthy and unhealthy foods, then the current strategies for obesity prevention may need to be revised. Encouraging low-income families to consume healthier but more costly foods to prevent future disease can be construed as an elitist approach to public health. Limiting access to inexpensive foods through taxes on frowned upon fats and sweets were a regressive measure. The broader problem may lie with growing disparities in incomes and wealth, declining value of the minimum wage, food imports, tariffs, and trade.

Naeem et al. (2007) the study was carried out to assess the profitability of sugarcane crop. For this purpose, a sample of 75 sugarcane growers in Faisalabad district was taken from randomly selected five villages, i.e 15 sugarcane growers from each village. Majority of them (78 %) were small farmers. Average yield of small and medium farmers was 23601 and 25438 kg per acre respectively. Net return of medium farmers was greater (Rs. 13910) than small farmers (Rs. 9315). There was not much difference in cost-benefit ratio of small and medium farmers, which was 2.04 and 2.18 respectively. The average yield per acre of sugarcane crop in Faisalabad was far below and cost of production per acre was higher than other districts of Punjab.

Hussain et al. (2011) stated that the economics of sugarcane production and its competitiveness in the up-and-coming open trade economy. The study was also analyzed the extent of policy bend and agricultural safeguard. The data on cost of production series of sugar cane crop were collected from the Agricultural Prices Commission (AP.Com). Punjab and Sindh, the two-major sugarcane producing provinces were the focus of the study. The Policy Analysis Matrix (PAM) was selected as analytical framework. The crop budgets were constructed both in financial and economic prices. The time series data from 1990-2002 on world prices of sugar cane and fertilizers (DAP and Potash) were utilized to estimate the

riskprices. These risk prices were later on utilized to estimate the economic risk prices. The Nominal Protection Coefficient for inputs (NPI) and output (NPC) and the Effective Protection Coefficient (EPC) was used to estimate the policy distortions. The Domestic resource cost ratio (DRC) was applied to show comparative advantage. Sugarcane is an important cash crop and provide raw material to nearly 78 Sugar factories. The excess supply and demand of sugar was cyclical in nature. Therefore, analysis was performed keeping in view both import and export parity prices. The analysis leads us to conclude that Pakistan (Punjab and Sindh) has no comparative advantage in producing sugar at export parity prices (price risk scenario), however, crop can be grown as an import substitution crop to cater the needs of sugar industry.

Baiyegunhi and Arnold (2011) they reported that the recent surge in input markets had serious implications for the South African cane growers. The Bureau for Food and Agricultural Policy (BFAP), had estimated that the aggregate South African farm input cost will rise by 53% in 2008. This situation was creating cash flow and solvency concerns for sugarcane growers. This study were attempt to examine the factors influencing sugarcane production on large scale farms, the resource use efficiency pattern and returns to scale to report evidence related to resource use and farm productivity. This study was based on data collected from a sample of 31 largescale sugarcane farmers in the Eshowe-Entumeni areas; these are farmers that produce in excess of 5000 tonnes seasonally. Given the increasing input prices in the sugarcane industry and management objective to minimize production costs, a double-log production function was estimated using the total sugarcane harvested in tonnes per hectare as dependent variable subject to the production costs. The result of the study indicates that farm staff and fertilizer was the most predominant costs item accounting for 62% of the total cost of production while the double log estimates revealed that the coefficients of all the explanatory variables included in the model were statistically significant in explaining the variation in sugarcane output on the farm. The result was further points to the non-optimal use of resources and a decreasing return to scale, hence the need for resource adjustment. Policy implication for potential increase in productivity and farm income was discussed.

Saranya et al. (2014) introduced the fungi-caused diseases in leaves were the most predominant diseases which appear as spots on the leaves. If not treated on

instance, causes the severe loss. Extreme use of pesticide for plant diseases treatment increases the cost and environmental pollution so their use must be minimized. This can be achieved by target the diseases places, with the correct quantity and concentration of pesticide by estimating disease severity using image processing method. Triangle thresholding and Simple threshold methods were used to segment the leaf area and disease region area correspondingly. Finally, diseases were categorising by calculating the quotient of disease area and leaf area. The exactness of the experimentation was found to be 98.60 %. Research indicates that this method to estimate leaf disease severity was fast and perfect**.**

2.5 Changing trend of energy use

Hetz (1992) carried out an experiment in south-central Chile between 1984 and 1988 on wheat, sugar beet, maize, beans, sunflower and potatoes. A total of 233 farmers participated in the project; they were divided into groups representing the most typical production systems for the different crops. The results showed that energy requirements from 1200-1600 M Cal/ha for dry beans to 4890-7620 M Cal/ha for seed potatoes. The energy efficiency of the crops ranged from 12.6-17.5 percent. Fuel and fertilizers (N and P) accounted for the largest share (75 per cent) of total energy expenditures. Energy efficiency could be improved by timely application of good agronomic practices to increase productivity.

Singh and Singh (2008) conducted that the flows of reactive N in terrestrial, aquatic and atmospheric ecosystems in India were being increasingly regulated by inputs, use efficiency and leakages of reactive N from agriculture. In the last three decades, use of reactive N in the form of chemical fertilizers had kept pace with the production of food grains, although the consumption is concentrated in certain areas with intensive farming. As for cereal-based agriculture, recovery of N by rice and wheat at on-farm locations in India rarely exceeds the 50% mark. Agricultural activities in India account for more than 80% of the total N2O emissions, including 60% from the use of N fertilizers and 12% from burning of agricultural residues. In Asia, reactive N transferred to the atmosphere by NH3 volatilization were expected to reach 19 Tg N yr–1 in the next three decades; 29% being India's contribution. Of the total anthropogenic emissions of NOx and N2O from Asian agriculture, about 68% was due to the combined contribution of India and China. Additionally, riverine discharge of dissolved inorganic N derived from N in river basins and leaching of

nitrate-N to the surface and ground water bodies also contributes to the application of reactive N in agriculture. Integrated management of organic amendments and fertilizer N can improve efficiency of reactive N use by crop plants, while achieving targets of productivity and quality. The greatest challenge in improving N use efficiency lies in developing precision management of reactive N in time and space. Approaches to maximize synchrony between crop-N demand and the supply of mineral N from soil resources along with reactive N inputs in high-yielding agricultural systems are critical towards this end. Among a host of upcoming technologies aimed at improving N management strategies, leaf colour charts, chlorophyll meters and optical sensors, which allow in-season estimation of N requirement of crops, were the most promising.

Monlik et al. (2008) forecasted the demand of energy limited to only commercial or conventional form of energy i,e. electricity and petroleum products. The energy demand estimations were restricted to six major crops, viz, paddy, wheat, sugarcane, cotton, oil seeds, and pulses. In terms of energy inputs in to agriculture the demand estimations were made in relation to land preparation fertilizer, pumping irrigation, harvesting and threshing. The percentage increase in energy consumption required to achieve 1per cent increase in crop production in 2000 turns out to be 2.1per cent for paddy, 1.4 per cent for wheat, 2.2 per cent for oil seeds, 7.9per cent for pulses, 1.6per cent for cotton and 5.5per cent for sugar cane. Thus, the output of wheat and cotton was likely to show much higher response to increase in energy input as compared to other crops.

Siddiqi et al. (2013) studied that the Pakistan's Indus Basin irrigation system, conceived initially as a vast network of gravity-fed canals, had evolved into a quasi-conjunctive management system in which pumped groundwater increasingly augments surface water supplies. Analysis of the evolution of on-farm energy use for agriculture in Punjab Province over the last 15 years, to find out that while total crop production increased 31%, direct energy intensity for agriculture increased 80%. Moreover, direct energy use was chiefly driven by groundwater pumping (61%). Important knowledge gaps were identified in the critical water energy-food inter dependencies that need to be addressed for sustainable management of scarce natural resources in Pakistan.

Baio et al. (2013) developed a computational model by linear programming based on web platform to select automatically mechanized agriculture system. From

software user can select a mechanized system in a list containing the specification and give best option at the lowest operational cost. The developed software is live on internet to have rational selection of mechanization system.

Atmaca et al. (2014) evaluated the solar energy potential of the South-Eastern Anatolia Region, the use of photovoltaic systems for irrigation were examined. With electrical energy produced from solar energy depending on the photovoltaic (PV) principle, in case of supply of necessary mechanical energy for the operation of submersible pump, some specifications of irrigation system with solar energy have been determined. With this aim, such as current, voltage and power electrical properties of the PV system including 4 modules which had totally 18x2=36 PV cells in each part had been calculated. In addition, PV system's efficiency, flow rate of the submersible pump and, hydraulic power rates had been calculated. In order to reduce the cost of the system, a DC pump is selected compatible with solar panels. So, the total cost including battery and inverter costs will be reduced. Because pump which work alternating current draw high power and will increase the number of solar cell.

Murthy and Madhuri (2015) studied that the peri-urban areas were characterized by great heterogeneity and rapid changes of land use. Furthermore, population composition changes as peri-urban areas offer attractive residential alternatives to city centres or more remote locations. The dynamic processes leave peri-urban areas in an in-between situation, neither city nor country side and home to a range of functions, spanning from agricultural production to residential and recreational areas. This paper investigates the urbanization of agricultural areas in the Greater Hyderabad region based on quantitative data collected on agricultural properties in 4 study areas between 1990 and 2012. The overall conclusion was that agricultural land use had continually largely unaffected by the processes of urbanization. However, most of the production was concentrated on a few very large full-time farms. In addition, the economic activities had been greatly diversified. The structural components of the areas (land use and landscape elements) thus appear to be more resilient than the socio-economic system (declining number of full-time farmers and increasing number of owners engaged in other gainful activities). However, at some point this discrepancy will disappear and rapid land use changes

may be expected. For an ideal urban land use, a balanced multi land use policy emphasizing peri-urban agriculture was suggested.

Kar and Raychaudhuri (2016) conducted that the Agricultural Sector occupies a pivotal position in the Indian Economy. We simply cannot survive without food, and therefore, without Agriculture. Energy was an essential component of Agricultural production. It fuels the equipment, irrigates the crops, fertilizes the soil, sustains the live stock, transports the food, and processes the food into its final forms. As the population continues to grow, more agricultural production was required to support the increased food demand. At the same time, Energy and Environmental constraint mandate that agricultural production be accomplished effectively with minimal Energy consumption. It was necessary to increase agricultural yield per unit area of land, while preserving the soil integrity and Environment. Efficient Energy Management practices will help to achieve and maintain the delicate balance. To tackle energy security, to implement India’s climate commitments, as well as to ensure food security and deal with water challenges, India must consider energy efficiency in Agricultural Sector. This paper deals with various challenges and wide variety of Energy efficient opportunities as related to sustainable Agriculture and Environment.

Greeshma et al. (2017) studied that the analysis of growth was used to find out the trend of a particular variable over a period of time and used for making policy decisions. The growth in the area, production and productivity of sugarcane *(Saccharum officinarum*) crop in Coastal Andhra region of Andhra Pradesh State was estimated using different linear and non-linear growth functions. The necessary secondary data were collected for a period of 40 years i.e., from 1973-74 to 2012-13. Growth rates were computed by using compound growth rates. Trend values were computed to study relative growth pattern. The future projections of area, production and productivity of sugarcane crop in Coastal Andhra region of Andhra Pradesh state up to 2019-20 AD were estimated upon the best fitted growth model. It was observed that quadratic function was the best fitted model for area and production whereas linear function for productivity. It was revealed from the results that area, production and productivity of sugarcane crop was increasing at a rate of 1.19 percent, 1.61 percent and 0.41 percent per annum, respectively.

MATERIAL AND METHODS

This chapter deals with the Selection of villages and farmers, categorization of farmers/farms and method employed for data collection, analysis and optimization of energy inputs to attain the objectives of the study.

3.1 Agro-climatic zone

The study was undertaken for the Madhya Pradesh which is located in the central part of India, extending from 17^0 48' to $26^0$52' north latitude and from $74^0$02' to $84^0$25' east longitude. Its rocks are among the oldest in the world, dating back to Pre-Cambrian and Paleoziocdays. Geologically the central India plateau is the part of Gondwana plate and through it running from West to East, is the only true rift – valley of the Tapti and Narmada rivers. The Vindhyanchal range of mountains meets the Satpura hills in Madhya Pradesh. The state land is surrounded by Utter Pradesh, Bihar, Orrisa, Chhattisgarh, Andhra Pradesh, Maharashtra, Gujrat and Rajasthan.

The state of Madhya Pradesh has been divided into 12 agro-climatic regions and 4 broad crop zones namely; Wheat zone, Rice-Wheat zone, Jowar-Wheat zone and Cotton-Jowar zone. The proposed survey work was undertaken in Rice-Wheat zone, Kymore Plateau and Satpura hill at district Jabalpur, Wheat zone, Vindhyachal Plateau at district Sehore, Jowar-Wheat zone, Satpura plateau district Gwalior and Cotton-Jowar zone, Malwa region. Madhya Pradesh is the largest state in the Indian Union. The state has about 5.3 million farming families cultivating 18.5% of land. The irrigated area is only 28% and main crops of the state are wheat, soybean, jowar, cotton and rice. The production varies from year to year due to uncertain monsoon rains. The locations of villages under study are shown in the map of Madhya Pradesh (Fig. 3.1)

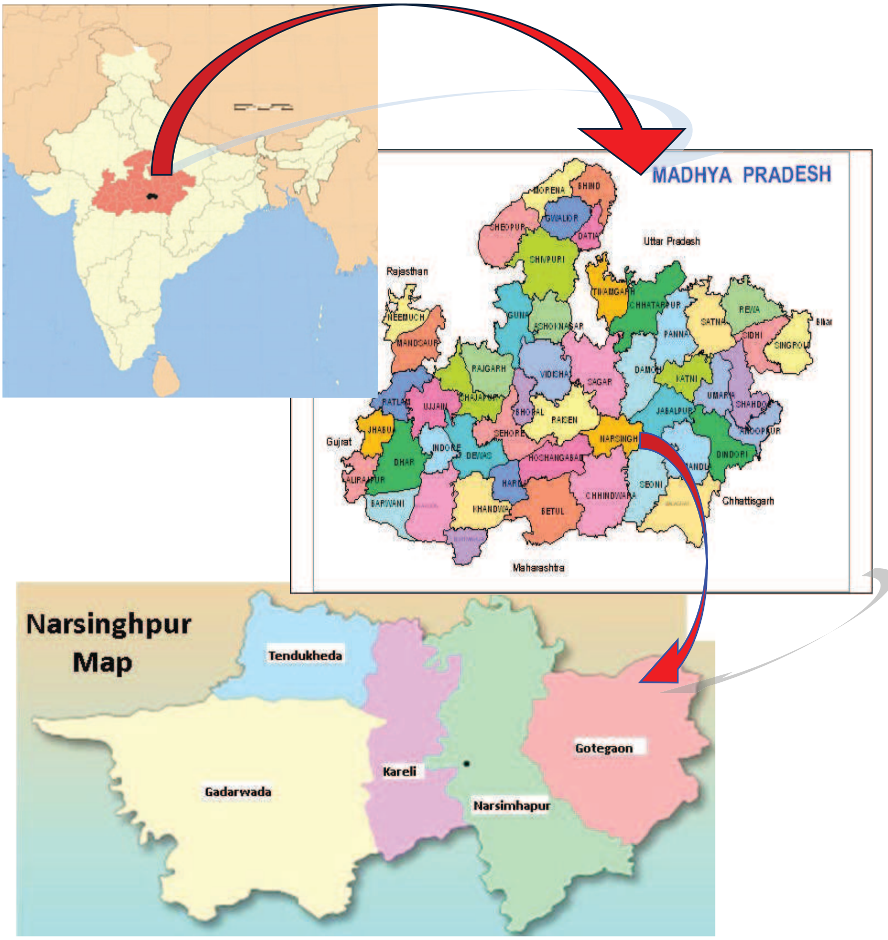

Fig. 3.1 Map for location of selected area under study of sugarcane in Narsinghpur district of Madhya Pradesh.

3.2 Selection of villages

Villages were selected on the basis of multistage stratified sampling method to represent the different agro-climatic area. of the state, in this study four villages were selected which covered wheat-rice, wheat-cotton and wheat-Jowar zone. While selecting village following parameters were also considered:

1. The population of the village should preferably be more than 1000.
2. Land holding should be well distributed under different category.
3. Urban effect should be minimum.
4. Co-operation of the resident of village should be proper.
5. The village should be well connected by road.

Data were collected on the pre-tested proforma by combination of recall method and by taking actual measurement if required. The physical data were then converted on common denominator by multiplying them with the appropriate energy equivalent coefficient (Annual report, ERAS, 1992). The details of the selected villages are as follows:

3.3 Selection of farmers

After selecting the villages for study, the farmers were randomly selected and contacted with the help of Gram-Pradhan. After collecting preliminary information related to their inventory, irrigation sources and type of farming system. It was tried that maximum farmers are contacted to have required information in present proforma.

3.4 Collection of data

The information including the quantity of energy inputs in the form of seed, fertilizers, chemicals, irrigation, human, animal, and prime movers. The output in the form of grain yield and by-product are to be determined from all the farmers of the villages falling in to different categories, further cropping pattern and hectare age under crop from farm to farm are also to be recorded. The operation time, fuel consumption, crop yield, and other parameters needed to be evaluated in a standardized manner as detailed by Mittal and Dhawan (1988).

The data was collected with the help of pre-designed, pretested questionnaire. The farmers were interviewed twice in rabi to collect information as

given in **Appendix 1**. This information includes information regarding farmers identifications, land holding, farm power and machinery availability, methods of irrigation, water availability. The utilization pattern of indirect source of energy viz. seed, fertilizer and chemicals. The proforma also included the details of power and machinery use for different field operations. The details of women/men and hired/owned labour were also received from the farmers. Various farm operations like fields operations, manure application and fertilizer application, sowing, irrigation, weeding/intercultural, plant protection, harvesting and threshing practices were interrogated with respect to power sources, fuel consumed per hour by the sources, implements used, hour of use of different implements with power sources, human power in term of hour both viz own and hired labour hour number.

The primary energy audit data of the villages for the sugarcane crop was computerized using computer program developed in the FORTRAN_77 language. The raw data collected were coded into required format for use of the computer. The individual farmer-wise following information were used:

- Source-wise input energy used, MJ/ha
- Operation-wise input energy used, MJ/ha
- Crop yield (kg/ha); area of farm, ha
- Inputs as nitrogen, phosphorus, potassium fertilizer use (kg/ha); seed use (kg/ha); FYM use (kg/ha)
- Use of man, women, animal, tractor, power tiller, engine, motor, petrol engine, kerosene engine, harvester, canal, (h/ha)

Implements and machinery use with each power source, (h/ha)

3.5 Availability of power

The inventory of hired (permanent and temporary) and family labour, draught animals (including all animals used for draught purpose carrying out agricultural operations), all power units including mobile (tractors) and stationary (diesel/gasoline engines and electric motors) were taken.

3.6 Theoretical consideration

Energy requirement for agriculture crop production is mainly obtained from human, animal, mechanical, and electrical energy sources.

3.7 Classification of energy

On the basis of the source, the energy can be classified as:

3.7.1 Direct sources of energy

The direct sources of energy are those which release the energy directly such as human labour, draught animals and mechanical and electrical power units. The direct energy may be further classified as renewable and non-renewable sources of energy.

3.7.2 Indirect sources of energy

The indirect sources of energy are those which do Not release energy directly but release it by conversion process. Some energy is spent in producing indirect sources of energy such as seeds, machinery, chemicals, fertilizer, etc. Indirect energy can be further classified as renewable and non-renewable sources of energy.

3.7.3 Renewable sources of energy

The renewable sources of energy are those, which can be subsequently replenished such as human energy, animal energy etc.

3.7.4 Non-renewable sources of energy

The Non-renewable sources of energy are those, which are not renewable in the near future, or which cannot be replenished. for example, coal, petroleum products, fertilizers, chemical etc.

3.7.5 Commercial sources of energy

Commercial sources of energy are those, which commercially produced. For example, Diesel, electricity, chemical, fertilizer, machinery etc.

3.7.6 Non- Commercial sources of energy

Direct and indirect energy of sources, which are not commercially produced, are called non-commercially sources of energy. For example, Human,

fuel wood, agricultural waste and farm yard manure (FYM). The various energy sources grouped under different categories are given in (Table 3.1)

Table 3.1 The various energy sources grouped under different categories

S. No.	Category of Energy	Source of Energy
1.	Direct energy	Human, Animal, Fuel wood, Agricultural waste, Petrol, Diesel, Electricity
2.	Indirect energy	Seed, Farmyard manure, Chemical, Fertilizer, Machinery.
3.	Renewable energy	Human, Animal, Fuel wood, Agricultural waste, Seed, Farmyard manure
4.	Non-renewable energy	Petrol, Diesel, Electricity, Chemical, Fertilizer, Machinery
5.	Direct renewable energy	Human, Animal, Fuel wood, Agricultural waste
6.	Direct non-renewable energy	Petrol, Diesel, Electricity
7.	Indirect renewable energy	Seed, Farmyard manure
8.	Indirect non-renewable energy	Chemical, Fertilizer, Machinery
9.	Commercial energy	Petrol, Diesel, Electricity, Chemical, Fertilizer, Machinery
10.	Non-commercial energy	Human, Animal, Fuel wood, Agricultural waste, Farmyard manure

3.8 Availability of farm machinery

The inventory of the all the farm machinery in the farm of the hand tools, bullock operated implements, tractor operated implements, power operated implements, and rural transport devices/vehicles available with the different categories of farmers was taken.

3.9 Crop yield

The crop yield was also recorded by interviewing the farmers of the selected villages. Information like harvested crop and threshed crop in terms of weight was recorded in the pretested questionnaires.

3.10 Cropping intensity

It is calculated by dividing the sum of the cropping area in the kharif and rabi seasons by the net cultivated area. It is often represented in percentage.

3.11 Specific energy

Energy requirement for per kilogram production of grain is known as productivity. It is defined as the total energy required to produce a unit weight of main product. It is calculated by dividing the total input energy by the yield of the main product and represented as MJ/kg.

3.12 Techniques for determining the variables

Operation wise and source wise energy consumption is to be calculated for wheat crop. Total energy, total yield and other calculation are to be also made for the analysis purpose.

3.12.1 Energy from Direct Sources

$$DE = HLH \times 1.96 + BPH \times 10.01 + FC \times 56.31 + EC \times 11.93 \quad \text{……..eq. 3.1}$$

Where,

DE = Direct Energy, (MJ)

HLH = Human labour hours use

BP = Bullock pair hours used, (h/ha)

FC = Fuel consumption, (l/ha)

EC = Electricity consumption, (kWh/ha)

3.12.2 Energy from Indirect Sources

$$IE = (C \times WM \times HUM \times OA) + FYM \times 0.3\ MJ/kg + S \times 14.7\ MJ/kg + Ch \times 120\ MJ/l \times \text{fertilizer}\ (N \times 60.0 \times P \times 11.1 \times K \times 6.7) \quad \text{…….eq. 3.2}$$

Where,

IE	= indirect energy input from machinery, (MJ)
C	= energy coefficient, (MJ/kg)
WM	= weight of machinery used per hour, (Kg)
HUM	= hours of use of machinery, (h)
OA	= operational area, (ha)
FYM	= Farm Yard Manure, (Kg/ha)
S	= seed, (Kg/ha)
Ch	= chemicals, (l/ha)
N	= nitrogen (kg)
P	= phosphorus (kg)
K	= potash (kg)

3.12.3 Total energy

$$TE = DE + IE \qquad \text{.........eq.3.3}$$

Where,

DE = Direct Energy, MJ

IE = Indirect Energy, MJ

3.13 Calculation of Energy computation

Operation-wise and source-wise energy computation was calculated for each crop under each farm category. Output-input energy ratio, specific energy and other energy calculation ware made for each crop. Energy coefficients used in calculations are given in Appendix I.

3.13.1 Mechanical power

Fuel consumption of tractor and diesel/petrol engines used for different farm operations wise calculated by the following equation:

$$F = \frac{LCF \times RHP \times SFC}{1000} \qquad \text{..........eq. 3.4}$$

Where,

F = Fuel consumption (l/h)

LCF = Load coefficient factor for different farm operations

RHP = Rated horsepower of power source in hp or kW

SFC = Specific fuel consumption (ml/hp/h) or (ml/kW/h)

The values of LCF and SFC for various power sources and type of farm work is given in Table 3.2

Table 3.2: The value of load coefficient factor (LFC) and specific fuel consumption (SFC) for various power source & type of work.

S. No.	Power source	Type of work	LFC	SFC (ml/kW/h)	SFC (ml/hp/h)
1.	Stationery	Water lifting	0.6	295	220
2.	Diesel Engine		0.8	295	220
3.	Tractor	Light work, e.g. transport, water-Lifting, etc.	0.4	282	210
		Medium work, e.g. secondary Tillage, sowing, inter-culture, Etc.	0.5	282	210
		Heavy work, e.g. Primary tillage, Harvesting, etc.	0.6	282	210
4.	Self-propelled Machine	Harvesting, etc.	0.7	282	210
5.	Small petrol engine	Spraying, dusting, etc.	0.8	671	500

Source: Energy in Panjab Agriculture (1996) Department of farm power and machinery PAU, Ludhiyana pp.8

3.13.2 Electric power

The electrical input for an electric motor was determined from the following formula:

$$E = RHP \times 0.746 \times \text{Hours of use} \times Ef. \qquad \text{………… eq. 3.5}$$

Where:

E = Electricity input (kWh)

RHP = Rated power of electric motor, hp

Ef = Efficiency of the system (may be taken as 0.80)

The electric input was recorded through energy meter in terms of units i.e. 1 unit = 1kWh

3.13.3 Man power

Manpower is one of the most important power sources on the farm. Energy equivalent for an adult man is taken as 1.96 MJ/man-h. The wages of a farm labour are taken as prevailing rate in a particular locality.

3.13.4 Animal power

Animal power is the major power source on the farm to perform the activities Like tillage and sowing, interculture, transportation of farm produce, seeds, fertilizers and even in threshing. The energy input of a pair of bullocks (having a body weight of about 450 kg) was assumed to be 10.10 MJ/pair-h.

3.13.5 Energy calculation for field operations

The energy used in the particular field operation was calculated as sum of human, animal, mechanical and electrical energy consumed. Energy consumption from both in terms of renewable and non-renewable energy and commercial and non-commercial energy sources (direct & indirect) was also quantified for different crops and cropping pattern.

3.14 Co-efficient for various sources of energy

Different sources of energy have different energy values. Some energy is invested to produce such sources of energy. Energy input may be in the form of food, feed, medicines, machinery and structures etc. Energy co-efficient for various

source of energy taken in to all forms of energy input to their production has been worked out, Dhawan & Mittal (1990).

Table 3.3 Equivalent coefficient for various sources of energy used for energy calculations

Items	Energy equivalent MJ/Unit
1. Human labour	
➢ Male	1.96 MJ/ man hr
➢ Female	1.57 MJ/ female hr
2. Bullock with a body weight 350-450 kg/ bullock	10.10 MJ/pair
3. Diesel	56.31 MJ/lit
4. Machinery*	
➢ Prime mover other than electric motor including self	64.8 MJ/kg
➢ Farm machinery other than propelled ones	62.7 MJ/kg
5. Electric motor	11.93 MJ/kWh
➢ Irrigation	45.88 MJ/hr
➢ Threshing	68.82 MJ/hr
6. Tractor	
➢ Ploughing	197 MJ/hr
➢ Threshing	169 MJ/hr
7. Fertilizer	60.0 MJ/kg
➢ Nitrogen	11.1 MJ/kg
➢ Phosphorus	6.7 MJ/kg
➢ Potash	0.3 MJ/kg
8. Farm Yard Manure	
9. Chemicals	
➢ Superior, needing dilution	120 MJ/lit
➢ Inferior, not needing dilution	10 MJ/kg
10. Crop	
➢ Sugarcane	5.3 MJ/kg

Machinery/equipment:

Calculation of energy through machinery/equipment is done by given coefficient (numerical) MJ/kg x hrs of use/life in years.

3.15 Effect of farm size

Operation-wise and source-wise energy used was calculated under different farm categories for each crop under study. Yield, output-input energy ratio and specific energy was also calculated on different farm categories and statistically compared at 5 per cent level of significance. Commercial/Non-commercial, renewable/non-renewable and direct/indirect energy use was also calculated for each farm category and for each crop.

3.16 Effect of cropping pattern

Operation-wise and source-wise energy use for different farm operation and Farm various sources was calculated for each cropping pattern under study. Individual farm operation and source was statistically compared for each crop rotation. Energy ratio for different cropping patterns was also compared. The use of commercial/non-commercial and renewable/non-renewable energy was also discussed for each crop rotation.

3.17 Statistical Analysis

The energy data was analyzed statistically. The mean and standard deviation of each of the parameter was calculated to test the significant difference in means. The ‘t’ test was applied to find the significance of difference between two means. The ‘t’ value was calculated by using the formula:

$$t = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{\dfrac{\left(\frac{1}{n_1} + \frac{1}{n_2} \right) \times \left(SD_1^2 \times n_1 + SD_2^2 \times n_2 \right)}{\left(n_1 + n_2 - 2 \right)}}}$$

…..eq.3.6

Where,

SD = Standard deviation = $(x_i - \overline{x})^2$

n_1 = Number of samples of mean $\overline{x}_1$

n_2 = Numbers of samples of mean x_2

3.18 Relationship Between productivity and total energy inputs

Relationship between total energy, MJ/ha (E_i) and total productivity, kg/ha (P_i) of the i^{th} farmer was established using function

$$P_i = f\,(E_i, A_i) \qquad \text{..................eq. 3.7}$$

E_i = Total energy inputs (MJ/ha) of i^{th} farmer

The statistical models used to establish the mathematical relations have been given In Table 3.5. The best-fit relation was selected based on:

- Value and significance of coefficient of multiple determination, R^2
- Logicality of sign and significance of coefficient of elasticity.
- Statistical closeness of observed and predicted production by plotting graph between the observed vs. predicted production.

Table 3.4 Mathematical relations used for best-fit relations

S.No.	Function's	Mathematical relationship
1.	Linear	$P = b_0 + b_1E + b_2A$
2.	Quadratic – linear (Energy - Area)	$P = b_0 + b_1E + b_2A + b_3E^2$
3.	Quadratic – quadratic (Energy - Area)	$P = b_0 + b_1E + b_2A + b_3E^2 + b_4A^2$
4.	Semi-log	$P = b_0 + b_1\ln(E) + b_2\ln(A)$
5.	Cobb-Douglas (Double-log)	$\ln(P) = b_0 + b_1\ln(E) + b_2\ln(A)$

The relation between yield, kg/ha (Y_i) and energy input, MJ/ha (X_i) was derived by dividing both sides be area (A_i) as under.

$$\mathrm{Pi/Ai} = 1/\mathrm{Ai}\{ f \ (\mathrm{Ei})$$ ....eq. 3.8

In case of Cobb-Douglas relation it will yield as

$$Y_i = f(X_i, A_i) \quad \text{if } \sum \beta \, \mathrm{p} \neq 1$$

$$Y_i = f(X_i) \quad \text{if } \sum \beta \, \mathrm{p} \neq 1$$

$$(\sum \beta \, \mathrm{p} = \text{sum of regression coefficients})$$

3.19 Optimization techniques

Statistical analysis of the data sets indicated that linear multiple regression technique was best suitable to the data sets, as R^2 values in most cases remained significant. Since the production models were found to be linear in character, linear programming technique was used to determine the optimized energy inputs for maximum yield obtainable from a given data set of energy inputs used by the farmers and corresponding yields obtained. Separate programs were design for the maximization of yield in three situations. Thus, the following three optimum farm plans were developed:

- Maximizing yield under existing level of technology
- Maximizing yield under improved level of cultivation technology. And
- Maximizing yield under simulated technology.

The systematic energy optimizing/management models were employed in this study. In this procedure, the data on energy consumption (source-wise, operation-wise) of individual farmer of a data set (of a selected group of farmers for production of sugarcane crop, depending upon the technology being used) has been considered. The objective function considers the data of energy usage and productivity of each farmer as a separate activity and defines the objective function and constraints as follows:

Let X_i denote the area allocated according to the energy usage of activity i in hectares and Y_i denote the yield (kg/ha) from the activity i. Then the objective function is:

Maximize Energy = $$\sum_{i=1}^{n} YiXi$$ ………eq. 3.9

3.19.1 Human energy

$$A_1 \leq \sum_{i=1}^{n} hiXi \leq A_2$$ ………eq. 3.10

Where,

h_1 = Human energy level for activity *i,* MJ/ha;

A_1 = Lower bound on human energy available per activity; and

A_2 = Upper bound on human energy available per activity.

3.19.2 Animal energy

$$A_{in} \leq \sum_{i=1}^{n} an_iX_i \leq A_{2n}$$ ……..eq. 3.11

Where,

ani = Animal energy level for activity *i,* MJ/ha;

A_{in} = Lower bound on animal energy available per activity; and

A_{2n} = Upper bound on animal energy available per activity.

3.19.3 Diesel energy

$$D_1 \leq \sum_{i=1}^{n} diXi \leq D_2$$ ……….eq. 3.12

Where,

d_i = Diesel energy level for activity *i,* MJ/ha;

D_1 = Lower bound on diesel energy available per activity; and

D_2 = Upper bound on diesel energy available per activity.

3.19.4 Electrical energy

$$E_1 \leq \sum_{i=1}^{n} e_i X_i \leq E_2 \qquad \text{.........eq. 3.13}$$

Where,

e_i = Electrical energy level for activity *i,* MJ/ha;

E_1 = Lower bound on electrical energy available per activity; and

E_2 = Upper bound on electrical energy available per activity.

3.19.5 Seed energy

$$S_1 \leq \sum_{i=1}^{n} s_i X_i \leq S_2 \qquad \text{........eq. 3.14}$$

Where,

s_i = Seed energy level for activity *i,* MJ/ha;

S_1 = Lower bound on seed energy available per activity; and

S_2 = Upper bound on seed energy available per activity.

3.19.6 Fertilizer energy

$$F_1 \leq \sum_{i=1}^{n} f_i X_i \leq F_2 \qquad \text{.........eq. 3.15}$$

Where,

f_i = Fertilizer energy level for activity *i,* MJ/ha;

F_1 = Lower bound on fertilizer energy available per activity; and

F_2 = Upper bound on fertilizer energy available per activity.

3.19.7 Machine energy

$$M_1 \leq \sum_{i=1}^{n} m_i X_i \leq M_2 \qquad \text{.........eq. 3.16}$$

Where,

m_i = Machine energy level for activity *i,* MJ/ha;

M_1 = Lower bound on machine energy available per activity; and

M_2 = Upper bound on machine energy available per activity.

3.19.8 Chemical energy

$$C_1 \leq \sum_{i=1}^{n} c_i X_i \leq C_2$$

………eq. 3.17

Where,

c_i = Agro-chemical energy level for activity *i,* MJ/ha;

C_1 = Lower bound on agro-chemical energy available per activity;

C_2 = Upper bound on agro-chemical energy available per activity.

3.19.9 Total energy

$$T_1 \leq \sum_{i=1}^{n} t_i X_i \leq T_2$$

………eq. 3.18

Where,

t_i = Total energy consumed by activity *i,* in MJ/ha;

T_1 = Lower bound on total energy available per activity in MJ/ha;

T_2 = Upper bound on total energy available per activity in MJ/ha.

The upper bound on total energy should not be exceed the sum of upper bound on all other constraints. Similarly, the lower bound on total energy should not be less than the sum of lower bounds on all other energy sources. For the present analysis the lower bound of all energy sources was taken as zero. When, $X_1 = 1, X_2 = X_3 = \ldots X_n = 0,$ we get yield (Y_1) obtained by the farmer $X_1$and the solution as same as the energies used by that activity (*farmer*). Hence, the objective function has logical interpretation.

$$\sum_{i=1}^{n} X_i = 1$$

………eq. 3.19

The ensure that the maximization of yield per hectare basis gives equal weight to each of the activities. The number of decision variables (or activates) included in the solution will be less than or equal to the number of constraints in the model. Once the solution for X_1's, say X^*_i's is obtained, the value of objective function (*i.e.* the value of the maximum yield) and usage of various energy sources are obtained using the expressions

$$\text{Yield} = \sum_{i=1}^{n} YiXi* \qquad \text{……..eq. 3.20}$$

$$\text{Human Energy} = \sum_{i=1}^{n} h_i X^*_i \qquad \text{……..eq. 3.21}$$

$$\text{Animal Energy} = \sum_{i=1}^{n} an_i X^*_i \qquad \text{……..eq. 3.22}$$

$$\text{Diesel Energy} = \sum_{i=1}^{n} d_i X^*_i \qquad \text{……..eq. 3.23}$$

$$\text{Electrical Energy} = \sum_{i=1}^{n} e_i X^*_i \qquad \text{……..eq. 3.24}$$

$$\text{Seed Energy} = \sum_{i=1}^{n} s_i X^*_i \qquad \text{……..eq. 3.25}$$

$$\text{Fertilizer Energy} = \sum_{i=1}^{n} f_i X^*_i \qquad \text{………eq.3.26}$$

Mechanical Energy = $\sum_{i=1}^{n} m_i X^*_i$

……..eq. 3.27

Chemical Energy = $\sum_{i=1}^{n} c_i X^*_i$

……..eq. 3.28

Total Energy = $\sum_{i=1}^{n} t_i X^*_i$

……..eq. 3.29

Since $t_i=h_i+an+d_i+e_i+f_i+s_i+m_i+c_i$, the sum of the energy usage from different sources shall be equal to the energy usage.

The values of the decision variables were similarly used for calculating the energy used in each operation. The choice of the constraints in the LP model can be need-based. It can be

- All sources of energy being considering
- All sources of energy and all active operations
- All active operations and energy sources not contributing to any operation

  The constraints may be appropriately formed in the model.

3.20 Energy Planning

To meet out the objectives, the following study has been conducted.

- Demographics details of the villages
- Status of farm equipment in the villages
- Farm power availability in the villages
- Energy use pattern for cultivation of sugarcane on different categories of farms in the villages
- Operation-wise energy input for rainfed (Animal and mixed) farms for sugarcane cultivation

- Optimal yield with average energy use sugarcane cultivation
- Optimal yield with use of improved package of practices for sugarcane cultivation
- Simulated data for potential yield for sugarcane cultivation
- Yield, energy ratio and specific energy requirement for sugarcane cultivation in five village of Madhya Pradesh
- Energy use from direct sources for sugarcane cultivation
- Projected energy requirement for different crops in Madhya Pradesh (2015-16)
- Compound growth for different crops in Madhya Pradesh (2015-16)
- Energy gap, yield gap and annual production loss for different crops in Madhya Pradesh.

RESULTS AND DISCUSSION

This chapter deals with the results obtained from the field studies and its interpretation of the sugarcane cultivation in the Narsinghpur district. This includes the demographic details. Under this study the following aspects were studied such as, energy use pattern through direct and indirect sources, farm machinery and power availability, changing energy use scenario in different rounds of survey, effect of operation wise energy requirement, source wise energy utilization, effect of farm category on energy use ,effect of level of field operation, effect of energy used through important sources, determination of energy coefficients, development of equations on the basis of actual energy use at the farmers field , optimization of energy use and prediction of energy requirement from different sources for required yield level of sugarcane for selected area, Narsinghpur district of Madhya Pradesh.

4.1 Agricultural Scenario of Madhya Pradesh

Madhya Pradesh is located in the central part of India, extending from 17°48' to 26° 52' north latitudes and from 74°02' to 84°25'east longitudes. Its rocks are among the oldest in the world, dating Back to Pre-Cambrian and Paleozoic days. Geologically the central India plateau is part of the Gondwana plate and through it running from west to east, is the only true rift-valleys of the Tapti and Narmada rivers. The Vindhyachal range of mountains meets the Satpura hills in Madhya Pradesh. The State is surrounded by many states like; Uttar Pradesh, Chhattisgarh, Andhra Pradesh, Maharashtra, Gujarat and Rajasthan.

Among the rural people of Madhya Pradesh are the tribal Gonds, Kols, Bhils, Muris and Oraons. Some of the tribes are still out of touch with the social and cultural world around them and believe in their traditional cultural practice.

The state of Madhya Pradesh occupying 30.74 Mha (44 Mha before separation of Chhattisgarh) geographical area is the largest state in the country with 45 districts and 313 development blocks (Khandelwal et al. 1993)

The forest coverage is 8.49 Mha being about 27.61 per cent of the geographical area. With about 77 per cent of the population living in rural area, agriculture is the main profession of its people. Agriculture and allied sectors

contribute about 44 per cent share in the state economy. The net sown area in Madhya Pradesh has been about 15.13 Mha (49.21 per cent of geographical area) with a cropping intensity of 137 per cent closely to that of the national average of 140 per cent. The state has been classified in 10 agro-climatic regions and 5 crop zones. The variety of soils ranging from rich clayey to gravely has been divided into 5 categories: alluvial, medium and deep black, shallow and medium black, mixed red and black, and red lateritic. The soils in the state are deficient in nitrogen (37 districts) and phosphate (23 districts) nutrients. 33 districts have been found to be deficient in zinc and 19 districts suffer from sulphur deficiency (Khandelwal et al. 1993)

At global level, total 121 countries are producing the sugarcane. Out of them some of important countries like Brazil, India, China, Thailand, Pakistan, Mexico, Cuba, Columbia, Australia, USA, Philippines, South Africa, Argentina, Myanmar and Bangladesh are producing approximately 80 per cent of total world production of sugarcane. Worldwide, sugarcane occupies an area of 20.42 million hectare with a total production of 1333 million metric tonnes. Sugarcane area and productivity differ widely from country to country. Brazil has the highest area i.e. 5.343 million hectares, while Australia has the highest productivity i.e. 85.1 tones/ha (Anonymous, 2009).

In India, the total area under sugarcane cultivation was reported to be about 49.18 lac hectare. The country produced about 3414.25 lac tonnes of cane at a national average of about 69.42 tonnes/ha in the year of 2015-16. India occupies the second rank in production of sugarcane in the world and contributes nearly 20.4 per cent area and 18.60 per cent production. The major sugarcane growing states are Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka and Madhya Pradesh etc. The area and production of sugarcane in Madhya Pradesh is about 0.73 lac hectare and 31.73 lac tones (FAO, 2015).

The production, yield and area of sugarcane in Madhya Pradesh is given in table nu. 4.1.

Table 4.1: Production, yield and area of Sugarcane in Madhya Pradesh

Year	Area 000' ha	Production 000'	Yield kg/ha
2011-12	49.70	196.80	3971
2012-13	54.10	276.00	5114
2013-14	73.10	361.30	4946
2014-15	111	457	41153
2015-16	103	528	51272

4.1.1 Human population details in Narsinghpur

The human population of farmers in Narsinghpur is shown in table no. 4.2.

Table 4.2: Details of population in Narsinghpur

Sr. No.	Particular	Narsinghpur district
1.	Geographical area (sq. km.)	513651
2.	Population-	1092141
	Male	567913
	Female	524228
3.	Literacy level (overall)-	77.12 percent
	Male	73465
	Female	147716
4.	Sex ratio per thousand males	910
5.	No. of Tehisils	05
6.	No. of Gram Panchayat	457
7.	No. of Zanpad Panchayat	06
8.	No. of villages	1052

The population of male is 567913 and the population of female is 524228 as per the sex ratio between male and female the female sex ratio per thousand of male population is 910.

4.2 Operation wise and source wise energy use pattern for sugarcane cultivation in Narsinghpur in 2013-14

Operation wise and source wise energy use pattern for cultivation of sugarcane in the selected area of Narsinghpur during 2013-14 is shown in table no.4.3

Table 4.3 Operation wise or source wise energy (MJ/ha) used in Narsinghpur district of Madhya Pradesh in 2013-14

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Operation wise energy (MJ/ha)											
Seedbed Preparation	5984.33	4818.04	4420.33	3233.72	4420.33	5953.09	3957.49	5396.2	4280.10	3571.09	4607.47
Sowing	43497.6	38153.6	38153.14	38080	40534	40926	38080	40730	33909	34105	38616.83
Interculture	4882.19	2987.39	1603.84	2405.76	2963.23	3241.96	872.45	3241.96	2623.87	2127.03	2694.96
Irrigation	103673.9	87390.31	82016.31	82016.31	76157.36	85446.31	70299.71	86394.8	58583.11	58583.11	79056.13
Fertilizer Application	20541	8494	10094	9865	10211	20541	11665	12047	7899	7899	11925.5
FYM Application	2071.03	-	-	1005.43	-	1426.46	-	1186.79	-	-	568.97
Plant protection	614.48	-	309.38	260.98	314.76	512.8	230.9	512.8	-	-	275.61
Harvesting	1176	1176	1097	980	1176	1176	980	1176	980	980	1089.70
Transportation	10405.15	10405.15	8344.95	5523.50	4185.58	4185.58	7432.17	22916.61	12386.94	5523.50	9130.91
Ratooning	196	196	156.80	147	156.80	156.80	196	156.80	156	147	166.52
Total	193041.69	153620.93	146195.75	143517.7	140119.26	163575	133713.72	173768	120818	112935.73	148130.6
Source wise energy (MJ/ha)											
Human	6096.4	4469.78	5147.83	5869.22	5584.53	9927.89	5752.6	5599.72	4936.26	4807.88	5819.21
Animal	-	404	-	-	-	-	606	-	151	-	116.10
Diesel Electricity	20395.48	17141.89	14540.36	10703.4	10443.25	13072.36	9960.11	29210.81	16538.24	10108.77	15211.46
Seed	100122.5	84430.8	77873	77873	72310	77873	66748.3	83435.4	55623.6	55623.6	75191.32
Fertilizer	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	37497.50
FYM	20400	8415	10015	9818	10123	20400	11577	11959	7828.5	7828.5	11836.40
Chemical	600	-	-	300	-	450	-	450	-	-	180.00
Machinery Total	538	-	150	180	303	360	150	360	-	-	204.10
Grand total Yield	2491.45	2321.96	2032.95	1674.14	1605.49	1741.88	1819.91	3003.36	2615.79	1442.05	2074.89
2013-14 q/ha	193041.69	153620.93	146195.64	143517.7	140119.26	163575.11	133713.72	173768	120818	112935.73	148130.6
Energy ratio	386083.38	307241.86	292391.39	287035.4	280238.52	327150.11	267427.44	347536	241636	225871.46	296261.2
Specific energy MJ/kg	1375	950	750	750	875	1125	750	1000	625	750	895.00
Productivity ratio	1.88	1.63	1.35	1.38	1.65	1.82	1.48	1.52	1.37	1.75	1.60
	2.80	3.23	3.89	3.82	3.20	2.90	3.56	3.47	3.86	3.01	3.31
	0.35	0.30	0.25	0.26	0.31	0.34	0.28	0.28	0.25	0.33	0.30

The irrigation is the main aspect, it has found through survey that for the requirement of the total input energy (MJ/ha) sugarcane cultivation in Narsinghpur district during 2013-14.

4.2.1 Energy input (MJ/ha) in Narsinghpur district 2013-14

In this study of 2013-14 heavy dependency was put on irrigation. However, in the survey, irrigation is till the major component to energy but there has been significant improvement in seed bed preparation and sowing resulting in the change in energy used pattern. In order to distinguished between the energy use patterns used by selected area surveys. Table 4.3 give the details of energy requirement for different operations under different categories of farmers for the year 2013-14.

4.2.2 Operation wise energy use pattern

The operation wise energy requirement for sugarcane cultivation varied between 112935.73 MJ/ha to 193041.69 MJ/ha with mean value of 148130.6 MJ/ha. Fig 4.1 shows that irrigation required maximum energy (53.36%) followed by Sowing (26.06%), fertilizer application (8.05%), transportation (6.16%), seed bed preparation (3.11%), interculture (1.81%), harvesting (0.73%), FYM application (0.38%), plant protection (0.18%), ratooning (0.11%) respectively the maximum operation wise energy was consumed by medium land holding farmers and it was lowest by small farms. The trend was not normal and it may be due to absence of winter rain for which farmers required maximum energy per unit area for irrigation due to smaller farm area and also hiring of water from neighbour.

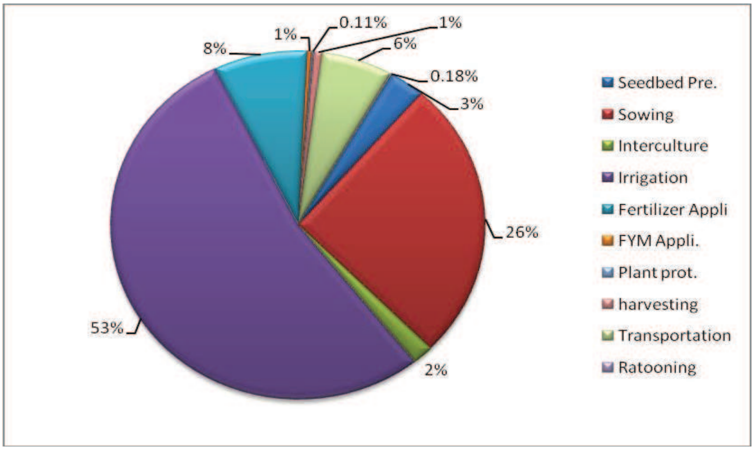

Fig 4.1 Operation wise energy use pattern for sugarcane (percentage) in Narsinghpur during 2013-14

4.2.3 Source wise energy use pattern

The main source of energy for production can be direct or indirect in nature the direct sources are those that release energy directly to the system as human and electrical energy etc. These are the most energy supplying sources. Among the indirect sources like seed fertilizer and chemical supply energy to the system through conversion process. These are useful for plant growth, but work done by the sources can be seen only after completion of conversion process. Machinery is also indirect source as they perform their work, but they are powered by direct sources like diesel and electricity etc. Total energy includes both direct and indirect sources. The fig 4.2 shows the source wise energy used pattern for sugarcane cultivation in Narsinghpur district during 2013-14.

Fig. 4.2 ditricted that the highest energy contributing source was electricity. Electricity provided maximum energy i.e 100122.5 MJ/ha during 2013-14. During 2013-14 irrigation consumed maximum energy but fertilizer used was minimum. This means that there exists no direct relation between irrigation and fertilizer used. The fertilizer contributed only 8.0 per cent of total energy. The survey revealed that, the use of manure was not sufficient in the selected area of Narsinghpur. Total average energy use by all sources were calculated and found to be 148130.6 MJ/ha during 2013-14 and minimum of 104908.45 MJ/ha during

the next year of 2014-15. In most years energy used varied between 104908.45 to 148130.6 MJ/ha.

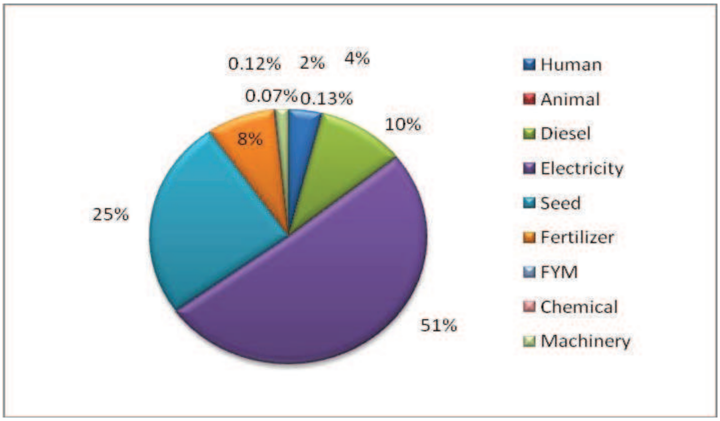

Fig 4.2 Source wise energy use pattern for sugarcane (percentage) in Narsinghpur during 2013-14

Seed is another energy contributing source in rabi season and sugarcane seed contributed between 33125 to 42400 MJ/ha. It contributed approximately 25 per cent of the total energy. The contribution of diesel was about 10.26 per cent of total. Initially during before nineteenth when bullock farming was common the contribution of diesel was only 2023 MJ/ha. Later years the use of diesel increased to a greater extent. The maximum contribution of diesel was observed during the year i.e 20395.48 MJ/ha, in the present study.

Use of animal was inversely proportional to use of diesel. During the survey it was revealed that, animal contributed 1161 MJ/ha during 2013-14. Human contributed 58192.10 MJ/ha during 2013-14 to 48362.6 MJ/ha during 2015-16. As the use of bullocks reduced the use of human labour also reduced. This does not mean that utility of human being reduced, only it can be said that now it is used for more quality work than for laborious work. Its contribution was 3.92 per cent during 2013-14. Overall it contributed 4.37 per cent of the total energy.

Use of machinery varied between 17611.1 MJ/ha to 20748.9 MJ/ha. As use of tractor drawn heavier implements increased the energy contribution by machinery increased. Total energy contribution by various sources varied

between 20748.9 MJ/ha (2013-14) to 17611.10 MJ/ha (2015-16). The variation occurs mainly due to variation in energy contribution by electricity and fertilizer. The per cent change in energy supplies for sugarcane production through different sources.

Table 4.3 shows that the total energy input from different sources was 148130.6 MJ/ha. The variation among the total energy input on the different farmers was 104741.88 to 148130.6 MJ/ha. The total energy consumed by large farmers (148130.6 MJ/ha) was found to be higher than that of small (104741.88 MJ/ha). Electricity and diesel contributed 50.76 and 10.26 per cent of total energy in 2013-14. Electricity operation was used for irrigation whereas diesel was used mainly for tillage or transportation. The energy inflow through electricity was 75191.32 MJ/ha followed by diesel 15211.46 MJ/ha. Among the indirect source of energy, the fertilizers supplied maximum (20400 MJ/ha). The policy on electric traffic for agricultural use has been varying. The past trend being provision of free electricity. Such policy defines to a great extent the pattern of use of electricity. On the other hand availability was very poor and irrigation.

4.3 Relation of energy from different classified sources and determination of energy coefficients area

Table 4.4 summarized the energy input under different category for the survey. Like; direct or indirect energy sources, renewable or non-renewable energy sources, direct renewable or direct non-renewable energy sources, indirect renewable or indirect non-renewable energy sources and commercial or non-commercial energy sources. There is a direct correlation between direct-indirect energy sources.

4.3.1 Direct- indirect energy ratio to productivity

Table 4.4 detracted that the relationship between direct and indirect source of energy and found that the direct and indirect source of energy. The increased the indirect source of energy then it was reduced the direct source of energy resulting in increased productivity. Table 4.4 also shows the direct-indirect ratio of productivity of sugarcane i.e 0.55, 0.47, 0.39, 0.40, 0.49, 0.53, 0.44, 0.42, 0.39 and 0.66 in 2013-14 for selected farmers.

Table 4.4 Direct energy sources and indirect energy sources for sugarcane cultivation (MJ/ha) in Narsinghpur 2013-14

Item		Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Direct energy sources (MJ/ha)												
Human		6096.4	4469.78	5147.83	5869.22	5584.53	9927.89	5752.6	5599.72	4936.26	4807.88	5819.22
Animal		-	404	-	-	-	-	606	-	151	-	116.10
Diesel		20395.48	17141.89	14540.36	10703.4	10443.25	13072.36	9960.11	29210.81	16538.24	10108.77	15211.46
Electricity		100122.5	84430.8	77873	77873	72310	77873	66748.3	83435.4	55623.6	55623.6	75191.32
Total		126614.38	106446.47	97561.19	94445.64	88337.78	100873.25	83067	118245.83	77249.10	70540.24	96338.00
Indirect energy sources (MJ/ha)												
Seed		42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	34497.5
Fertilizer		20400	8415	10015	9818	10123	20400	11577	11959	7828.5	7828.5	11836.4
Chemical		538	-	150	180	303	360	150	360	-	-	204.1
FYM		600	-	-	300	-	450	-	450	-	-	180.0
Machinery		2491.45	2321.96	2032.95	1674.14	1605.49	1741.88	1819.91	3003.36	2615.79	1442.05	2074.89
Total		66429.45	47174.46	48635.45	49072.14	51781.49	62701.88	50646.91	55522.36	43569.29	42395.55	48792.89
Grand total		249748.71	200812.73	189383.83	183589.42	177967.55	210074.38	170174.62	233756.22	159228.89	112935.79	145130.89
Yield q/ha	2013-14	1375	950	750	750	875	1125	750	1000	625	750	895.00
Productivity kg/MJ		0.55	0.47	0.39	0.40	0.49	0.53	0.44	0.42	0.39	0.66	0.61

4.3.1.1 Direct energy sources (MJ/ha)

Direct energy sources from the selected area of Narsinghpur during 2013-14 is shown in fig 4.3 it was found that the farmers were used the human energy (5819.22 MJ/ha), animal energy (116.10 MJ/ha), diesel energy (15211.46 MJ/ha) and electrical energy (75191.32 MJ/ha) respectively. The percentage of direct energy sources like human, animal, diesel and electricity is varied as human (6.04%), animal (0.12%), diesel (15.78%) as well as electricity (78.04%) for the sugarcane cultivation year during 2013-14.

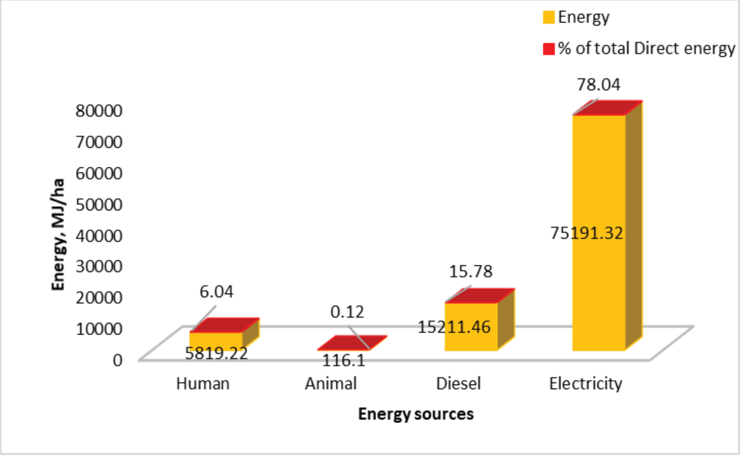

Fig 4.3 Direct energy sources (MJ/ha) in Narsinghpur during 2013-14

4.3.1.2 Indirect energy sources (MJ/ha)

During the study of direct energy sources from the selected area of Narsinghpur in 2013-14. Shown in fig 4.4 we found that the farmers were also used indirect energy sources like; seed, fertilizer, chemical, FYM and machinery energy sources. For seed energy (34497.5 MJ/ha), fertilizer energy (11836.4 MJ/ha), chemical energy (204.10 MJ/ha), FYM energy (180 MJ/ha) and machinery energy (2074.89 MJ/ha). The percentage of indirect energy sources like; seed, fertilizer, chemical, FYM and

Machinery is varied as seed (70.7%), fertilizer (24.25%), chemical (0.41%), FYM (0.36%) as well as machinery (4.25%) in the sugarcane cropping year 2013-14.

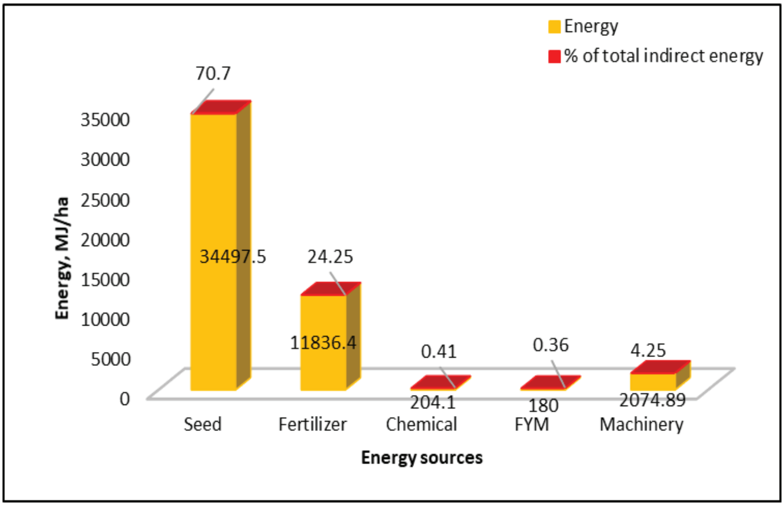

Fig 4.4 Indirect energy sources (MJ/ha) in Narsinghpur during 2013-14

4.3.2 Renewable- Nonrenewable energy ratio to productivity

Over the years of study, shown in table 4.5 there is an increased dependency on nonrenewable source of energy and reduction in renewable source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the renewable- nonrenewable ratio to the productivity from 0.71, 0.61, 0.51, 0.52, 0.62, 0.68, 0.56, 0.57, 0.51 and 0.66 for different operation at different farmers field in the year of 2013-14.

Table-4.5 Renewable energy sources and non-renewable energy sources (MJ/ha) in Narsinghpur 2013-14

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Renewable energy sources (MJ/ha)											
Human	6096.4	4469.78	5147.83	5869.22	5584.53	9927.89	5752.6	5599.72	4936.26	4807.88	5819.21
Animal	-	404	-	-	-	-	606	-	151	-	116.10
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	34497.5
FYM	600	-	-	300	-	450	-	450	-	-	180.0
Total	49096.4	41311.28	41585.33	43269.22	45334.53	50127.89	43458.6	45799.72	38212.26	37932.88	40612.81
Non-renewable energy sources (MJ/ha)											
Diesel	20395.48	17141.89	14540.36	10703.4	10443.25	13072.36	9960.11	29210.81	16538.24	10108.77	15211.46
Electricity	100122.5	84430.8	77873	77873	72310	77873	66748.3	83435.4	55623.6	55623.6	75191.32
Chemical	538	-	150	180	303	360	150	360	-	-	204.1
Fertilizer	20400	8415	10015	9818	10123	20400	11577	11959	7828.5	7828.5	11836.4
Machinery	2491.45	2321.96	2032.95	1674.14	1605.49	1741.88	1819.91	3003.36	2615.79	1442.05	2074.89
Total	143947.43	112309.65	104611.31	100248.54	94784.74	113447.27	90255.32	127968.47	82606.13	75002.92	104518.17
Grand total	193043.83	153620.98	146196.64	143517.76	140119.27	163575.13	133713.92	173768.19	120818.39	112935.80	145130.98
Yield q/ha 2013-14	1375	950	750	750	875	1125	750	1000	625	750	895.00
Productivity kg/MJ	0.71	0.61	0.51	0.52	0.62	0.68	0.56	0.57	0.51	0.66	0.61

4.3.2.1 Renewable energy sources (MJ/ha)

During the study of renewable energy sources from the selected area of Narsinghpur in 2013-14 are shown in fig 4.5. It was found that the farmers were used the human energy (5819.22 MJ/ha), animal energy (116.10 MJ/ha), seed energy (34497.5 MJ/ha) and FYM energy (180.00 MJ/ha). The percentage of renewable energy sources like human, animal, seed and FYM is varied as human (14.32%), animal (0.28%), seed (84.94%) as well as FYM (0.44%) in the sugarcane cropping year 2013-14.

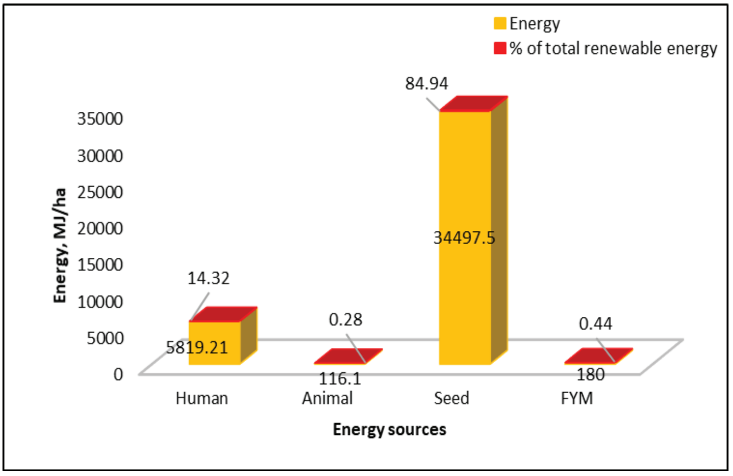

Fig 4.5 Renewable energy sources (MJ/ha) in Narsinghpur during 2013-14

4.3.2.2 Non-renewable energy sources (MJ/ha)

During the study of non-renewable energy sources from the selected area of Narsinghpur in 2013-14 are shown in fig 4.6. It was found that the farmers were used non-renewable energy sources like; diesel, electricity, chemical, fertilizer and machinery energy sources. For diesel energy (15211.46 MJ/ha), electricity energy (75191.32 MJ/ha), chemical energy (204.10 MJ/ha), fertilizer energy (11836.4 MJ/ha) and machinery energy (2074.89 MJ/ha). The percentage of non-renewable energy sources

like; diesel, electricity, chemical, fertilizer and Machinery is varied as diesel (14.55%), electricity (71.94%), chemical (0.19%), fertilizer (10.36%) as well as machinery (1.98%) in the sugarcane cropping year 2013-14.

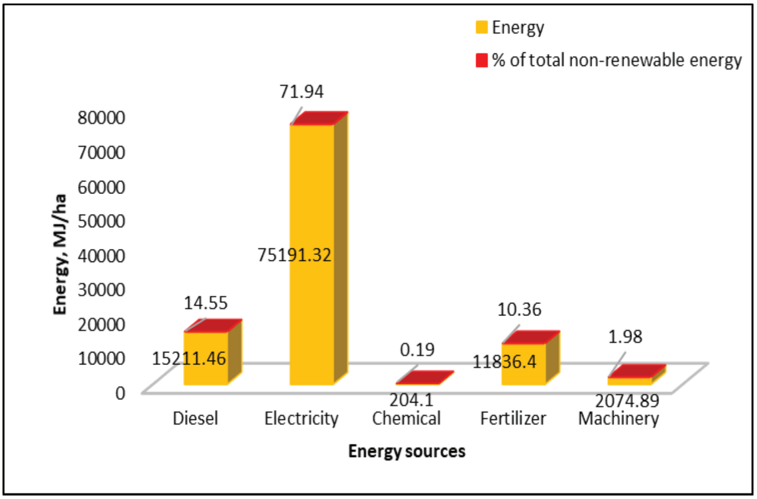

Fig 4.6 Non-renewable energy sources (MJ/ha) in Narsinghpur during 2013-14

4.3.3 Direct renewable- direct nonrenewable energy ratio to productivity

Table 4.6 shows that there is an increased dependency on direct non-renewable source of energy and reduction in direct renewable source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the direct renewable- direct nonrenewable ratio to the productivity from 1.08, 0.89, 0.76, 0.79, 0.99, 1.11, 0.90, 0.84, 0.80 and 1.06 in the year of 2013-14.

Table-4.6 Direct renewable or direct non-renewable energy sources (MJ/ha) in Narsinghpur 2013-14

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Direct renewable energy sources (MJ/ha)											
Human	6096.4	4469.78	5147.83	5869.22	5584.53	9927.89	5752.6	5599.72	4936.26	4807.88	5819.21
Animal	-	404	-	-	-	-	606	-	151	-	116.10
Total	6096.4	4873.78	5147.83	5869.22	5584.53	9927.89	6358.60	5599.72	5087.26	4807.88	5935.31
Direct non-renewable energy sources (MJ/ha)											
Diesel	20395.48	17141.89	14540.36	10703.4	10443.25	13072.36	9960.11	29210.81	16538.24	10108.77	15211.46
Electricity	100122.5	84430.8	77873	77873	72310	77873	66748.3	83435.4	55623.6	55623.6	75191.32
Total	120517.98	101572.69	92413.36	88576.4	82753.25	90945.36	76708.41	112646.11	72161.84	65732.37	90402.78
Grand total	126614.38	106446.47	97561.19	94445.62	88337.78	100873.25	83067.01	118245.83	77249.10	70540.24	96338.08
Yield q/ha 2013-14	1375	950	750	750	875	1125	750	1000	625	750	895.00
Productivity kg/MJ	1.08	0.89	0.76	0.79	0.99	1.11	0.90	0.84	0.80	1.06	0.92

4.3.3.1 Direct renewable energy sources (MJ/ha)

During the study of direct renewable energy sources from the selected area of Narsinghpur in 2013-14 are shown in fig 4.7. It was found that the farmers were used the human energy (5819.21 MJ/ha) and animal energy (116.10 MJ/ha). The percentage of direct renewable energy sources like human and animal is varied as human (98.04%), animal (1.95%) in the sugarcane cropping year 2013-14.

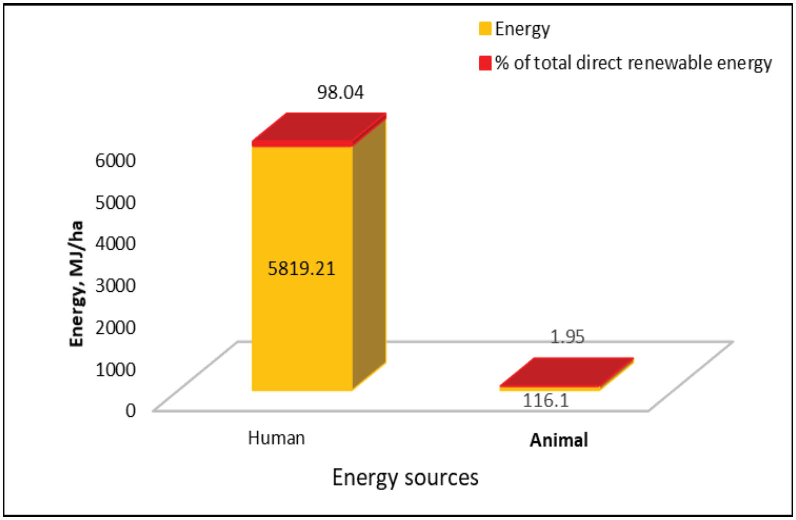

Fig 4.7 Direct renewable energy sources (MJ/ha) in Narsinghpur during 2013-14

4.3.3.2 Direct non-renewable energy sources (MJ/ha)

During the study of direct non-renewable energy sources from the selected area of Narsinghpur in 2013-14. Shown in fig 4.8 we found that the farmers were used direct non-renewable energy sources like; diesel and electricity energy sources. For diesel energy (15211.46 MJ/ha) and electricity energy (75191.32 MJ/ha). The percentage of direct non-renewable energy sources like; diesel and electricity is varied as diesel (16.82%) and electricity (83.17%) in the sugarcane cropping year 2013-14.

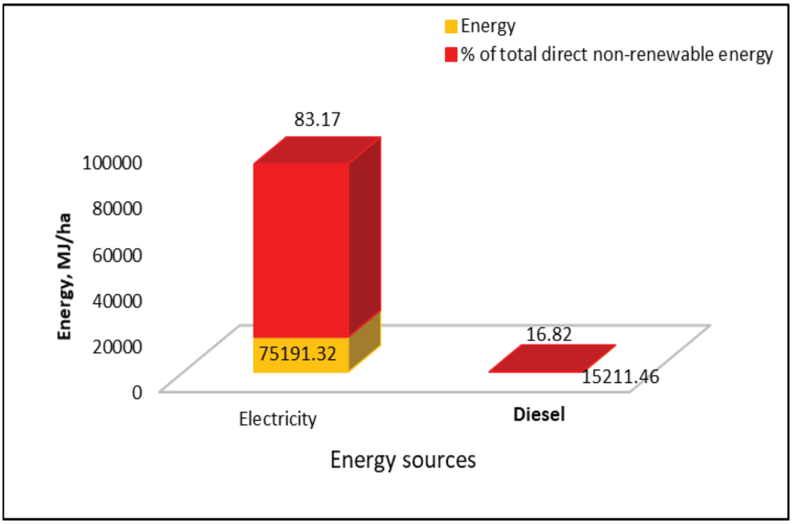

Fig 4.8 Direct non- renewable energy sources (MJ/ha) in Narsinghpur during 2013-14

4.3.4 Indirect renewable- indirect nonrenewable energy ratio to productivity

Over the years of study, sown in table 4.7 there is an increased dependency on indirect renewable source of energy and reduction in indirect non-renewable source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the indirect renewable- indirect nonrenewable ratio to the productivity from 2.06, 2.01, 1.54, 1.52, 1.68, 1.79, 1.48, 1. 80, 1.43 and 1.76 in the year of 2013-14.

Table-4.7 Indirect renewable energy and indirect non-renewable energy sources (MJ/ha) in Narsinghpur 2013-14

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Indirect renewable energy sources (MJ/ha)											
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	34497.5
FYM	600	-	-	300	-	450	-	450	-	-	180.0
Total	43000	36437.5	36437.5	37400	39750	40200	37100	40200	33125	33125	34677.50
Indirect non-renewable energy sources (MJ/ha)											
Chemical	538	-	150	180	303	360	150	360	-	-	204.1
Fertilizer	20400	8415	10015	9818	10123	20400	11577	11959	7828.5	7828.5	11836.4
Machinery	2491.45	2321.96	2032.95	1674.14	1605.49	1741.88	1819.91	3003.36	2615.79	1442.05	2074.89
Total	23429.45	10736.96	12197.95	11672.14	12031.49	22501.88	13546.91	15322.36	10444.29	9270.55	14115.39
Grand total	66429.45	47174.46	48635.45	49072.14	51781.49	62701.88	50646.91	55522.36	43569.29	42395.55	48792.89
Yield q/ha 2013-14	1375	950	750	750	875	1125	750	1000	625	750	895.00
Productivity kg/MJ	2.06	2.01	1.54	1.52	1.68	1.79	1.48	1.80	1.43	1.76	1.83

4.3.4.1 Indirect renewable energy sources (MJ/ha)

During the study of indirect renewable energy sources from the selected area of Narsinghpur in 2013-14. Shown in fig 4.9 we found that the farmers were used the seed energy (34497.5 MJ/ha) and FYM energy (180.00 MJ/ha). The percentage of indirect renewable energy sources like seed and FYM is varied as seed (99.48%), FYM (0.51%) in the sugarcane cropping year 2013-14.

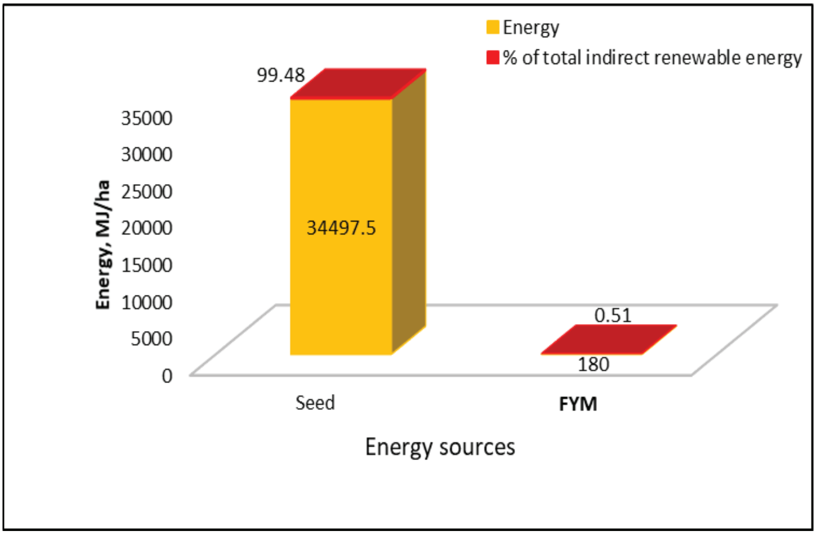

Fig 4.9 Indirect renewable energy sources (MJ/ha) in Narsinghpur during 2013-14

4.3.4.2 Indirect non-renewable energy sources (MJ/ha)

During the study of indirect non-renewable energy sources from the selected area of Narsinghpur in 2013-14. Shown in fig 4.10 we found that the farmers were used indirect non-renewable energy sources like; chemical, fertilizer and machinery energy sources. For chemical energy (204.10 MJ/ha), fertilizer energy (11836.4 MJ/ha) and machinery energy (2074.89 MJ/ha). The percentage of indirect non-renewable energy

sources like; chemical, fertilizer and machinery is varied as chemical (1.44%), fertilizer (83.85%) and machinery (14.69%) in the sugarcane cropping year 2013-14.

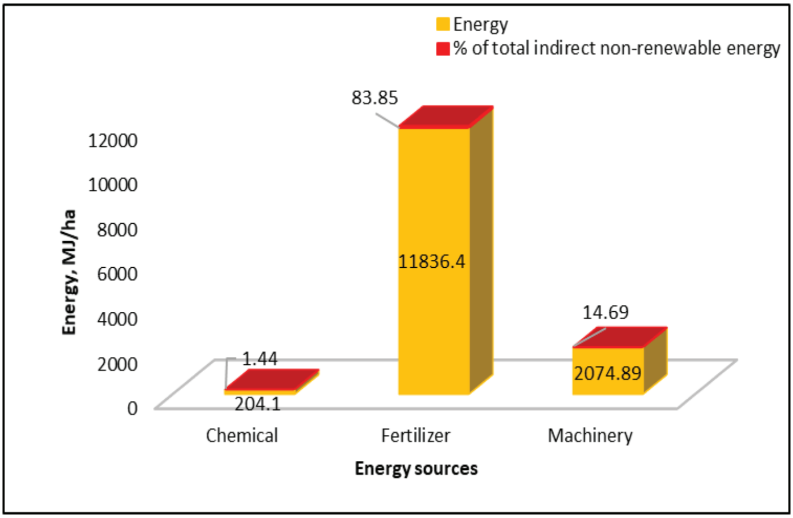

Fig 4.10 Indirect non-renewable energy sources (MJ/ha) in Narsinghpur during 2013-14

4.3.5 Commercial and non-commercial energy ratio to productivity

Over the years of study, sown in fig 4.8 there is an increased dependency on commercial source of energy and reduction in non-commercial source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the commercial – noncommercial energy ratio to the productivity from 0.91, 0.81, 0.68, 0.70, 0.87, 0.90, 0.77, 0.74, 0.71 and 0.93 in the year of 2013-14.

Table-4.8 Commercial or non-commercial energy sources (MJ/ha) in Narsinghpur 2013-14

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Commercial energy sources (MJ/ha)											
Diesel	20395.48	17141.89	14540.36	10703.4	10443.25	13072.36	9960.11	29210.81	16538.24	10108.77	15211.46
Electricity	100122.5	84430.8	77873	77873	72310	77873	66748.3	83435.4	55623.6	55623.6	75191.32
Chemical	538	-	150	180	303	360	150	360	-	-	204.1
Fertilizer	20400	8415	10015	9818	10123	20400	11577	11959	7828.5	7828.5	11836.4
Machinery	2491.45	2321.96	2032.95	1674.14	1605.49	1741.88	1819.91	3003.36	2615.79	1442.05	2074.89
Total	143947.43	112309.64	104611.31	100248.54	94784.74	113447.24	90255.32	127968.46	82606.13	75002.92	104518.17
Non- Commercial energy sources (MJ/ha)											
Human	6096.4	4469.78	5147.83	5869.22	5584.53	9927.89	5752.6	5599.72	4936.26	4807.88	5819.21
Animal	-	404	-	-	-	-	606	-	151	-	116.10
FYM	600	-	-	300	-	450	-	450	-	-	180.0
Total	6696.4	4873.78	5147.83	6169.22	5584.53	10377.89	6358.6	6049.72	5087.26	4807.88	6115.31
Grand total	150643.83	117183.42	109759.14	106417.76	100369.27	123825.13	96613.92	134018.18	87693.39	79810.81	10633.48
Yield q/ha 2013-14	1375	950	750	750	875	1125	750	1000	625	750	895.00
Productivity kg/MJ	0.91	0.81	0.68	0.70	0.87	0.90	0.77	0.74	0.71	0.93	0.80

4.3.5.1 Commercial energy sources (MJ/ha)

During the study of commercial energy sources from the selected area of Narsinghpur in 2013-14. Shown in fig 4.11 we found that the farmers were used the diesel energy (15211.46 MJ/ha), electricity energy (75191.32 MJ/ha), chemical energy (204.10 MJ/ha), fertilizer energy (11836.4 MJ/ha) and machinery energy (2074.89 MJ/ha). The percentage of commercial energy sources like; diesel, electricity, chemical, fertilizer and machinery is varied as diesel (14.55%), electricity (71.94%), chemical (0.19%), fertilizer (11.32%) and machinery (1.98%) in the sugarcane cropping year 2013-14.

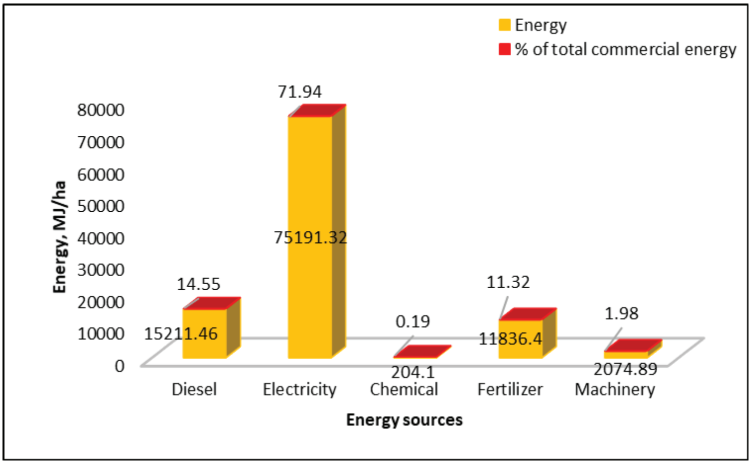

Fig 4.11 Commercial energy sources (MJ/ha) in Narsinghpur during 2013-14

4.3.5.2 Non-commercial energy sources (MJ/ha)

During the study of non-commercial energy sources from the selected area of Narsinghpur in 2013-14. Shown in fig 4.12 we found that the farmers were used non-commercial energy sources like; human, animal and FYM energy sources. For human energy (5819.21 MJ/ha), animal energy (116.10 MJ/ha) and FYM energy (180 MJ/ha). The percentage of non-commercial energy sources like; human, animal and FYM is varied as human (95.15%), animal (1.89%) and FYM (2.94%) in the sugarcane cropping year 2013-14.

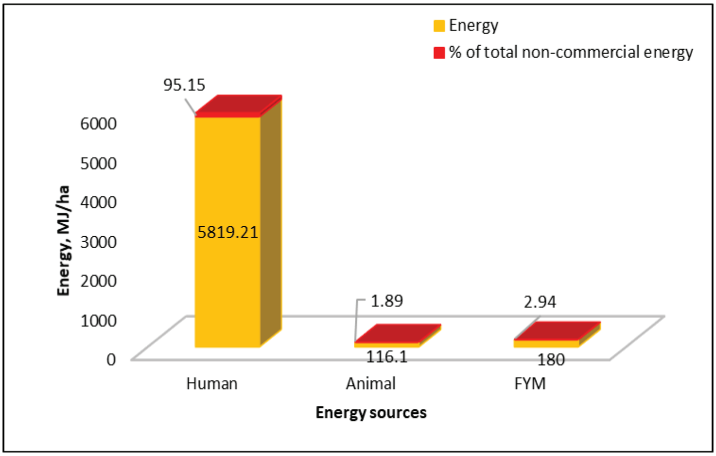

Fig 4.12 Non-commercial energy sources (MJ/ha) in Narsinghpur during 2013-14

4.4 Effect of seedbed preparation on yield

Effect of seedbed preparation on yield can be evaluated separately for selected area in different years of survey. The data of different round cannot be cumulated as productivity is affected by various parameters in a particular year including weather effect. The relationship is shown for year of 2013-14 (Effect is also discussed for the year 2013-14).

4.4.1 Narsinghpur

The seedbed preparation energy consumption pattern for the year 2013-14 under tractor farming system shows that on an average the seedbed preparation energy consumption was 4607.47 MJ/ha. The tractor farming was more useful for sugarcane cultivation. The value for yield showed a great production on an average value of 10 farmers from the selected area was 895 Q/ha respectively. The higher productivity under tractor farming reveals that the farmers under this farming systems were from mainly medium farm categories. These are the farmers who are not lacking as far as the physical inputs like fertilizers and water as well they had close look to their farming operations this resulted in to higher output-input energy ratio.

Fig 4.13 shows the relationship between seedbed preparation& yield for the facts as stated above in selected area Narsinghpur. Their relationship can be seen in the equation given below:

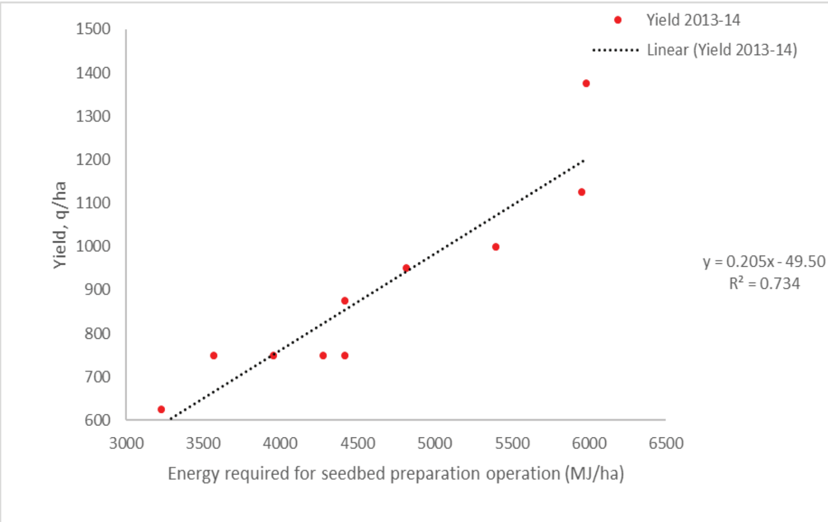

Fig. 4.13 Effect of seedbed preparation on yield of sugarcane (Narsinghpur, 2013-14)

$$Y = 0.2052x - 49.504 \qquad \text{......eq. 4.1}$$

$$(R^2 = 0.7344)$$

Considering seedbed preparation as predictor and yield of sugarcane as response for all equations derived by statistical analysis using software "SPSS" and MS-Excel. Fig.4.13 presents the relationship for the year 2013-2014.

The relationship between yield & seedbed preparation energy is positive and direct. However, statistically their relation is significant. Value of R^2 = 0.734.

4.5 Effect of sowing on yield

Effect of sowing on yield can be evaluated separately for selected area in different years of survey. The relationship is shown for year of 2013-14 (Effect is also discussed for the year 2013-14).

4.5.1 Narsinghpur

The sowing energy consumption pattern for the year 2013-14 under tractor farming system shows that on an average the sowing energy consumption was 38616.83MJ/ha. The tractor farming was more useful for sugarcane cultivation. The value for yield showed a great production on an average value of 10 farmers from the selected area was 895 q/ha respectively. The higher productivity under tractor farming reveals that the farmers under this farming systems were from mainly medium farm categories. These are the farmers who are not lacking as far as the physical inputs like fertilizers and water as well they had close look to their farming operations this resulted in to higher output-input energy ratio.

Fig 4.14 shows the relationship between sowing & yield for the facts as stated above in selected area Narsinghpur. Their relationship can be seen in the equation given below:

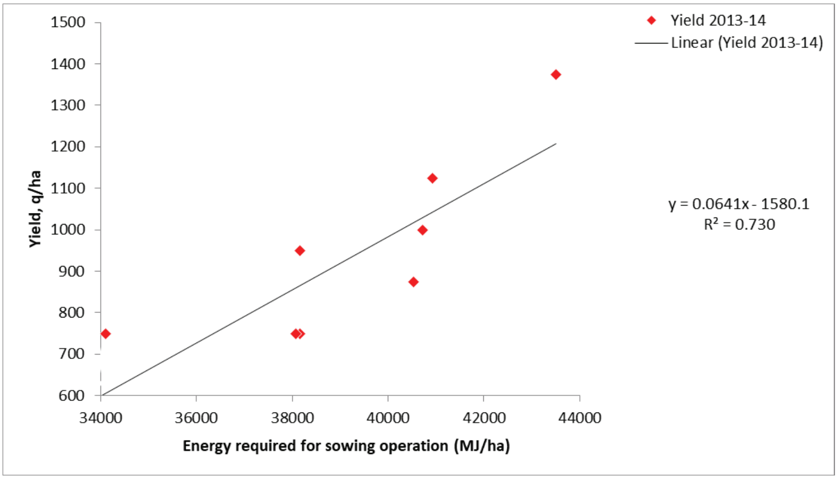

Fig. 4.14 Effect of sowing on yield of sugarcane (Narsinghpur, 2013-2014)

$$y = 0.0641x - 1580.1 \qquad \text{.......eq. 4.2}$$
$$(R^2 = 0.7301)$$

Considering sowing as predictor and yield of sugarcane as response for all equations derived by statistical analysis using software "SPSS" and MS-Excel. Fig.4.14 presents the relationship for the year 2013-2014.

The relationship between yield & sowing energy is positive and direct. However statistically their relation is significant. Value of R^2 = 0.730.

4.6 Effect of interculture on yield

Effect of interculture on yield can be evaluated separately for selected area in different years of survey. The relationship is shown for year of 2013-14 (Effect is also discussed for the year 2013-14).

4.6.1 Narsinghpur

In the year 2013-14 it is observed that interculture required approximately 2694.96 MJ/ha under the tractor farming. Bullock farming is not considered as numbers of observation were low. The result approves the information derived from the selected area Narsinghpur. The yields under the bullock farming were 625 q/ha as compare to 1375 q/ha under tractor farming. The output-input energy ratio was 1.88 and 1.37 for mix and tractor farming and their respective values for specific energy were 3.89 and 2.90 as stated earlier mix farmer used comparatively higher physical inputs like chemical fertilizer as compared to tractor farmers.

Fig 4.15 shows the relationship between interculture & yield for the facts as stated above in selected area of Narsinghpur. Their relationship can be seen in the equation given below:

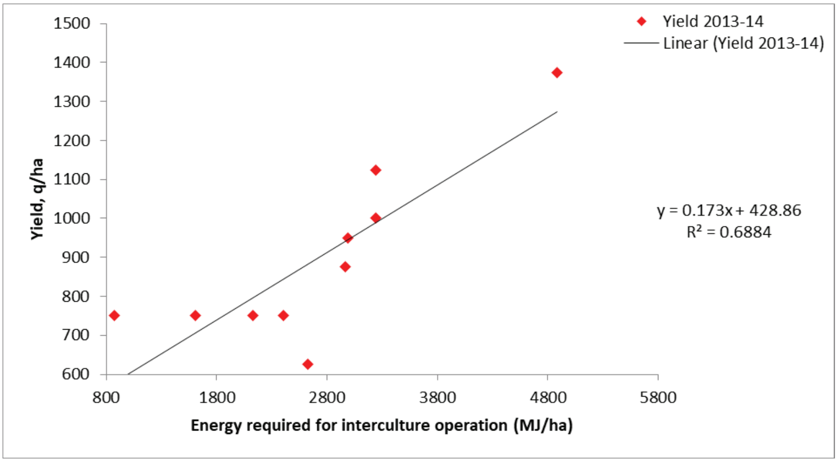

Fig. 4.15 Effect of interculture on yield of sugarcane (Narsinghpur, 2013-14)

Looking to fig 4.15 and equation derived to show the relationship among interculture energy use and productivity in the Narsinghpur for the year 2013-14 it can be said that there is a great effect of level of interculture on the yield of sugarcane in the Narsinghpur. There exist great scopes to enhance the yield by increasing Interculture. The relationship is strong and positive.

$$y = 0.173x + 428.86 \qquad \text{......eq. 4.3}$$
$$(R^2 = 0.6884)$$

Considering interculture as predictor and yield of sugarcane as response for all equations derived by statistical analysis using software “SPSS” and MS-Excel. Fig.4.15 presents the relationship for the year 2013-14.

The relationship between yield & interculture energy is positive and direct. However statistically their relation is significant. Value of $R^2 = 0.688$.

4.6 Effect of irrigation on the yield of sugarcane

The relationship between yield and irrigation energy is also considered for the year 2013-14. The effect of irrigation for the selected area Narsinghpur can be detailed as below:

4.6.1 Narsinghpur:

The crop sugarcane was grown by the farmers after paddy crop. It is also cultivated by the farmers had fellow land during kharif. In Narsinghpur "Havelli" system was used in which rainfall water is stored during rainy season. In this system land used to be sloppy at the center like ponds so, water do not loss by runoff. In the Narsinghpur most of the farmers possessed tube well and the farmers, who did not have water source, hired the irrigation water from neighboring farms. The relation between irrigation energy and yield is shown in fig 4.16 for the selected area Narsinghpur. By considering irrigation energy as predictor and yield as response they can be co-related with the following equation.

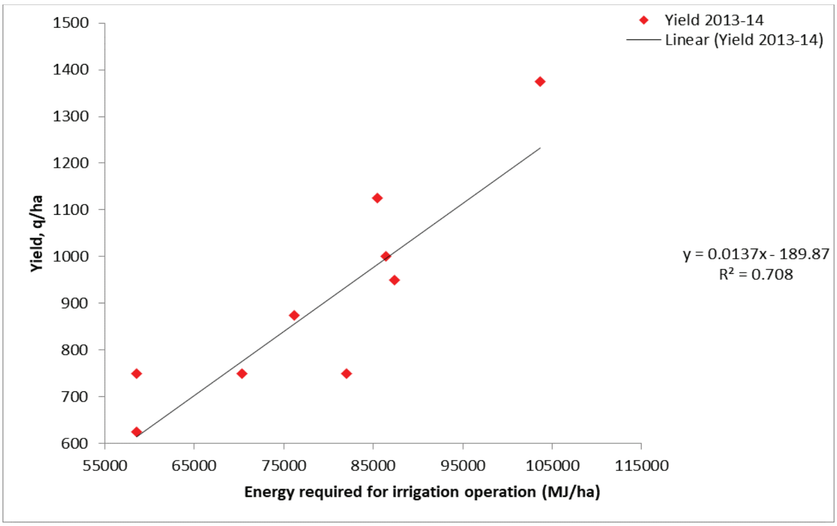

Fig. 4.16 Effect of irrigation on the yield of sugarcane (Narsinghpur, 2013-14)

$$y = 0.0137x - 189.87 \qquad \text{..............eq. 4.4}$$

$$(R^2 = 0.7086)$$

Higher irrigation energy means either higher number of irrigation or more hours of water supply in each irrigation. In these years the water reached to the plants by free flow. Most of the farms had slope for movement of the water. The variation in irrigation energy was too much and there were few farmers who did

not apply any irrigation and totally dependent on winter or summer rains. The results revealed that un-irrigated fields average yield was only 625 q/ha which was less than half of the average yield in the selected area of Narsinghpur. The choice of sugarcane crop by the farmers has been based on availability of assured irrigation. The farmers without assured irrigation did not inclined to select sugarcane crop rather they selected other crop like; wheat, urid, black gram, green gram etc. These relations were found stronger when the data of farmers survey of the year 2013-14 was considered.

It means in the selected area Narsinghpur there was a significant enhancement in the yield of sugarcane with increased in water supply during the cropping period of sugarcane. Above fact can also be seen when this relationship is drawn for individual farmer.

Fig 4.16 shows irrigation level is one of the most effective factors to enhance yield of sugarcane in the Narsinghpur. The data of the year 2013-14 of the selected area Narsinghpur shows that there exists strong and positive co-relation between energy consumption for irrigation and productivity of sugarcane. They are significantly co-related at 1 per cent level of significance.

4.7 Effect of Fertilizer energy on the yield of sugarcane

There are number of inputs which are essential for the production of sugarcane out of all the physical inputs the fertilizers gave comparatively higher impact in production agriculture. Therefore, it has become essential to discuss the effect of fertilizer on the yield of sugarcane in the selected area for survey.

4.7.1 Narsinghpur

In the year 2013-2014 except 8 farmers all have applied chemical fertilizer. Approximate yield of 625 q/ha was observed for the farmers who did not use fertilizer. On the other hand the use of fertilizer energy varied to a great extent and the value of fertilizer energy varied between 7899 MJ/ha to 20541 MJ/ha in the year 2013-2014. Whereas, the corresponding value of yield of sugarcane was 625 Q/ha and 1375Q/ha. Fig 4.17 Shows the relationship and can be expressed mathematically as.

$$y = 0.0406x + 411.09 \qquad \text{.................eq.4.5}$$
$$(R^2 = 0.736)$$

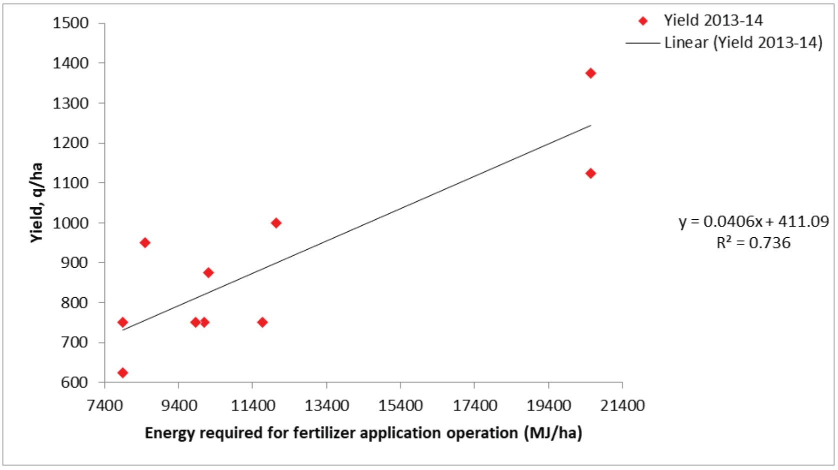

Fig. 4.17 Effect of fertilizer on the yield of sugarcane (Narsinghpur, 2013-14)

It means higher yield can be obtained by increasing use of agro fertilizer in the selected area Narsinghpur (fig 4.17). Looking to the effect at individual farmers field. The energy from fertilizer was minimum of 7899 MJ/ha and maximum of 20541 MJ/ha the corresponding yield was 625 q/ha and 1375 q/ha.

Fig 4.17 clearly speaks that higher the application of chemical fertilizer energy more will be the production of sugarcane in Narsinghpur. It is mainly due to the reason that farmers are still far away from the recommended dose of fertilizer. But they realized the importance of chemical fertilizer and the energy contribution by fertilizer increased to about certain limit (20541 MJ/ha) the quantity of fertilizer application almost stagnant. The application of FYM reduced abruptly during the last decade. This is one reason to increase use of fertilizer to increased yield.

From the figure it can be also concluded that there needs to be the intensive use of fertilizer for the production of sugarcane in the Narsinghpur as in

the year of 2013-14 there existed a positive and strong co-relation between application of energy through fertilizer and productivity of sugarcane.

4.8 Operation wise and source wise energy use pattern (MJ/ha) in Narsinghpur during 2013-16

Operation wise and source wise energy use pattern for cultivation of sugarcane in the selected area of Narsinghpur from 2013 to 2016. The detail of operation wise and source wise energy use pattern from 2013 to 2016 are shown in Table no. 4.9.

4.8.1 Total energy input (MJ/ha) in Narsinghpur from 2013 to 2016

In the study from 2013 to 2016 heavy dependency was put on irrigation. However, in the survey, irrigation is till the major component to energy but there has been significant improvement in seed bed preparation and sowing resulting in the change in energy use pattern. In order to distinguished between the energy use patterns used by selected area surveys. Table 4.9 give the details of energy requirement for different operations under different categories of farmers for the year from 2013 to 2016.

Table-4.9 Total operation wise or source wise energy (MJ/ha) used in Narsinghpur District of Madhya Pradesh during 2013 to 2016

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Operation wise energy (MJ/ha)											
Seedbed Pre	5984.33	4818.04	4420.33	3233.72	4420.33	5953.09	3957.49	5396.2	4280.10	3571.09	4607.47
Sowing	43497.6	38153.6	38153.14	38080	40534	40926	38080	40730	33909	34105	38616.83
Interculture	14646.57	8962.17	4811.52	7217.28	8889.69	9725.88	2616	9725.88	7871.61	6381.09	8084.88
Irrigation	311021.7	262170.93	246048.93	246048.93	228472.08	256338.93	210899.13	259184.4	175749.33	175749.33	237168.39
Fertilizer	61623	25482	30282	29595	30633	61623	34995	36141	23697	23697	35776.5
Appli. FYM	6213.09	-	-	3016.29	-	4279.38	-	3560.37	-	-	1706.91
Appli. Plant protection	1843.44	-	928.14	782.91	944.28	1538.4	692.7	1538.4	-	-	826.83
Harvesting	3528	3528	3291	2940	3528	3528	2940	3528	2940	2940	3269.1
Transportation	31215.45	31215.45	25034.85	16570.5	12556.74	12556.74	22296.51	68749.83	37160.82	16570.5	27392.73
Ratooning	588	588	470.4	441	470.4	470.4	588	470.4	468	441	499.56
Total	480161.18	374918.19	353440.85	347925.63	330448.52	396939.82	317064.83	429024.48	286075.86	263455.01	357949.2
Source wise energy (MJ/ha)											
Human	15842.46	13007.54	15085.79	15461.46	14974.89	27220.97	15062.6	14633.36	13025.98	12267.64	15658.25
Animal	-	1212	-	-	-	-	1818	-	453	-	348.3
Diesel	49885.02	39440.65	32379.36	26163.86	23153.53	27975.36	22447.41	77413.29	41810.16	23822.49	36449.1
Electricity	300367.5	253292.4	233619	233619	216930	233619	200244.9	250306.2	166870.8	166870.8	225573.96
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	37497.50
Fertilizer	61200	25245	30045	29454	30369	61200	34731	35877	23485.5	23485.5	35509.2
FYM	1800	-	-	900	-	1350	-	1350	-	-	540.00
Chemical	1614	-	450	540	909	1080	450	1080	-	-	612.30
Machinery	9048.64	6088.32	5268.51	4540.5	4205.91	4615.08	5016.87	8485.8	7150.53	3736.77	5597.11
Total	482157.62	374723.41	353285.16	347778.82	330292.33	396810.41	316870.78	428895.65	285920.97	263308.2	357785.72
Grand total	962318.8	749641.6	706726.01	695704.45	660740.85	793750.23	633935.62	857920.13	571996.83	526763.21	715734.92
Yield q/ha 2013-16	3575	2700	2250	2400	2375	3000	2325	3075	1875	2175	2575
Energy ratio	1.96	1.90	1.68	1.82	1.90	2.00	1.94	1.89	1.73	2.18	1.90
Specific energy MJ/kg	2.69	2.77	3.14	2.89	2.78	2.64	2.72	2.78	3.05	2.42	2.77
Productivity kg/MJ	0.37	0.36	0.31	0.34	0.35	0.37	0.36	0.35	0.32	0.41	0.35

4.8.2 Operation wise energy use pattern

The operation wise energy requirement varied between 263455.01 MJ/ha to 480161.18 MJ/ha with mean value of 357949.20 MJ/ha. Fig 4.18 shows that irrigation required maximum energy (66.22%) followed by sowing (10.78%), fertilizer application (9.99%), transportation (7.65%), interculture (2.25%), seed bed preparation (1.28%), harvesting (0.91%), FYM application (0.47%), plant protection (0.23%), ratooning (0.13%). The maximum operation wise energy was consumed by medium land holding farmers and it was lowest by small farms. The trend was not normal and it may be due to absence of winter rain for which farmers required maximum energy per unit area for irrigation due to smaller farm area and also hiring of water from neighbour.

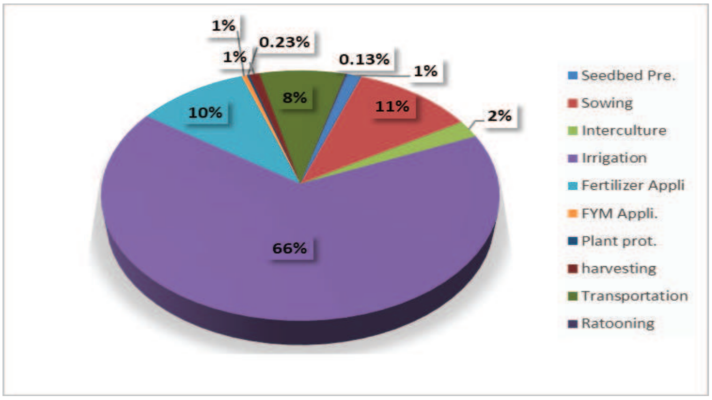

Fig 4.18 Total operation wise energy use pattern for sugarcane (percentage) in Narsinghpur during 2013 to 2016

4.8.3 Source wise energy use pattern

The main source of energy for production can be direct or indirect in nature the direct sources are those that release the energy directly to the system as human electrical etc. These are the most energy supplying sources. Among the indirect sources like seed fertilizer and chemical they supply the energy to the system through conversion process. These are useful for plant growth, but work done by the sources can be seen only after completion of conversion process. Machinery is also indirect

source as they perform their work, but they are powered by direct sources like diesel electricity etc. Total energy includes both direct and indirect sources.

Fig. 4.19 shows that the first highest energy contributing source was electricity. Electricity provided minimum of 166870.8 MJ/ha during the year 2013 to 2016 and maximum of 300367.5 MJ/ha during 2013 to 2016. During 2013 to 2016 irrigation consumed maximum energy but fertilizer use was minimum. This means that there exists no direct relation between irrigation and fertilizer use. The fertilizer contributed 9.92 % of total energy. The use of farmyard manure was not enough in selected area Narsinghpur during survey. Total average energy use by all sources were 357949.2 MJ/ha during 2013 to 2016 and minimum of 263455.01 MJ/ha during the year of 2013 to 2016. In most years energy used varied between 104908.45 to 357785.72 MJ/ha.

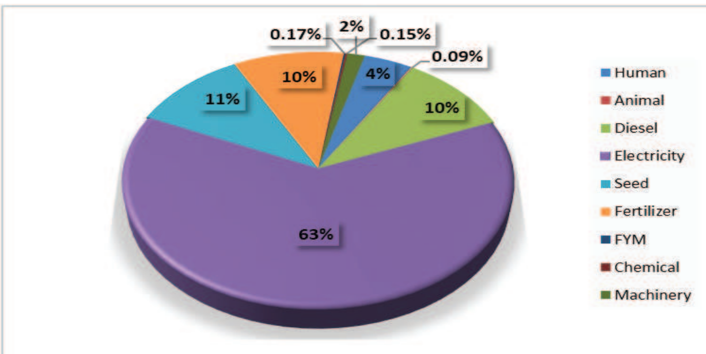

Fig 4.19 Total source wise energy use pattern for sugarcane (percentage) in Narsinghpur during 2013 to 2016

Seed is another energy contributing source in rabi season and sugarcane seed contributed between 33125 to 42400 MJ/ha during survey. It contributed approximately 10.48 % of the total energy. The contribution of diesel was about 10.18 % of total. Initially during 2013 to 2016 when bullock farming was common the contribution of diesel was only 2023 MJ/ha. later years the use of diesel increased to a greater extent. The maximum contribution of diesel was observed during the year 2013 to 2016 (49885.02 MJ/ha)

Use of animal was inversely proportional to use of diesel. During the survey animal contributed 3483 MJ/ha during 2013-16. Human contributed 58192.10 MJ/ha during 2013-14 to 156582.50 MJ/ha during 2013-16. As the use of bullocks reduced the use of human labour also reduced. This does not mean that utility of human being reduced, only it can be said that now it is used for more quality work than for laborious work. Its contribution was 3.92 % during 2013-14. Overall it contributed 0.09% of the total energy from 2013-16.

Uses of machinery vary between 20748.9 MJ/ha to 55971.10 MJ/ha. As use of tractor drawn implements increased being heavier the energy contribution by machinery increased. Total energy contribution by various sources vary between 20748.9 MJ/ha (2013-14) to 55971.10 MJ/ha (2013-16). The variation occurs mainly due to variation in energy contribution by electricity and fertilizer. The % change in energy supplies for sugarcane production through different sources.

Table 4.9 shows that the total energy input from different source was 357785.72 MJ/ha. The variation among the total energy input on the different farmers was 148130.6to357785.72 MJ/ha. The total energy consumed by large farmers (357785.72 MJ/ha) was found to be higher than that of small (148130.6 MJ/ha). Electricity and diesel contributed 63.04 and 10.18% of total energy in 2013-16. Electricity was used for irrigation whereas, diesel was used mainly for tillage or transportation. The energy inflow through electricity was 225573.96 MJ/ha followed by diesel 36449.10 MJ/ha. Among the indirect source of energy, the fertilizers supplied maximum (61200 MJ/ha) (Table 4.9). The policy on electric traffic for agricultural use has been varying. The past trend being provision of free electricity. Such policy defines to a great extent the pattern of use of electricity. On the other hand, availability was very poor and irrigation.

The difference in total energy use is not significant. Use of electricity produced in last 3 years 2013-14 or 2015-16 may be due to the intense use of comparatively efficient methods of irrigation (sprinkler). In Narsinghpur also the use of agro chemical for weeding and insects control was not found popular for sugarcane production.

One of the reasons of fewer yields in the Narsinghpur region during early survey was production of other crop during kharif season which resulted in to comparatively poor yield of sugarcane in rabi season.

Table 4.10 Energy from different classified sources and determination of energy coefficients in Narsinghpur 2013 to 2016

Energy (MJ/ha)	**Survey years (2013 to 2016)**
Direct energy	278029.61
Indirect energy	76756.11
Renewable energy	51044.05
Non renewable energy	303741.67
Direct renewable energy	16006.65
Direct non-renewable energy	262023.06
Indirect renewable energy	35037.5
Indirect non-renewable energy	41718.61
Commercial energy	303741.67
Non-commercial energy	16546.55
Direct-indirect energy ratio	3.62
Renewable – non-renewable energy ratio	0.16
Direct renewable-direct non renewable energy ratio	0.06
Indirect renewable-indirect non renewable energy ratio	0.89
commercial –non-commercial energy ratio	18.35
Productivity (kg/MJ)	0.35
Yield (q/ha)	2575
Specific energy (MJ/kg)	2.77
Output-input energy ratio (MJ/unit)	6.86

Consumption of machinery energy has not increased significantly since seed bed preparation and sowing mainly done by traditional bullock drawn Dufan or Tractor drawn light cultivator/bund former. Tilth level was not considered as important factor affecting yield of sugarcane.

4.9 Energy inputs

Table 4.10 reveals that ratio of total direct to indirect energy sources from 2013 to 2016 was 3.62. It means use of physical energy input increased in every next survey as well use of diesel and electricity remains almost the same. The commercial or non-commercial energy source and its ratio was 18.35 during 2013 to 2016. The main reason is the increased use of diesel and fertilizers with time.

The ratio of renewable energy to non-renewable energy use was 0.16 in 2013 to 2016. The variations in energy use pattern have been found encouraging. The productivity increased from 0.30 kg/MJ during 2013 and 0.35 kg/MJ during 2016. The yield increased from 895 Q/ha (2013) to maximum of 2575 Q/ha (2016) the increment of 34.75%. The requirement of energy for the unit yield of sugarcane has been found in increasing order and its minimum value were 148130.6 MJ/ha and increase to 357949.2 MJ/ha during 2013-16, the increment of 41.38% of energy. The energy use efficiency can be evaluated by energy ratio and the significant increase in output- input energy ratio was observed. Its value was 6.86 during 2013 to 2016. These ratios are comparatively higher than other agricultural allied business the reason is inclusion of energy of leaf and residues which used to be equal. In weight thus, it can be concluded that sugarcane production in Narsinghpur has become highly energy efficient during the recent years as compared to early 10-15 years back.

4.10 Relation of energy from different classified sources and determination of energy coefficients area

Table 4.11 summarized the energy input under different category for the survey. Like; direct or indirect energy sources, renewable or non-renewable energy sources, direct renewable or direct non-renewable energy sources, indirect renewable or

indirect non-renewable energy sources and commercial or non-commercial energy sources. There is a direct correlation between direct- indirect energy sources.

4.10.1 Direct- indirect energy ratio to productivity:

Over the years of study, shown in table 4.11 there is an increased dependency on indirect source of energy and reduction in direct source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the direct- indirect ratio to the productivity from 0.69, 0.72, 0.63, 0.69, 0.71, 0.75, 0.73, 0.71, 0.65 and 0.82 in the year of 2013 to 2016.

Table 4.11 Direct energy sources and indirect energy sources (MJ/ha) in Narsinghpur 2013-16

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Direct energy sources (MJ/ha)											
Human	15842.46	13007.54	15085.79	15461.46	14974.89	27220.97	15062.6	14633.36	13025.98	12267.64	15658.25
Animal	-	1212	-	-	-	-	1818	-	453	-	348.3
Diesel	49885.02	39440.65	32379.36	26163.86	23153.53	27975.36	22447.41	77413.29	41810.16	23822.49	36449.1
Electricit	300367.5	253292.4	233619	233619	216930	233619	200244.9	250306.2	166870.8	166870.8	225573.96
y Total	366094.98	306952.59	281084.15	275244.32	255058.42	288815.33	239572.91	342352.85	222159.94	202960.93	278029.61
Indirect energy sources (MJ/ha)											
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	34497.5
Fertilizer	61200	25245	30045	29454	30369	61200	34731	35877	23485.5	23485.5	35509.2
Chemical	1614	-	450	540	909	1080	450	1080	-	-	612.30
FYM	1800	-	-	900	-	1350	-	1350	-	-	540.00
Machinery	9048.64	6088.32	5268.51	4540.5	4205.91	4615.08	5016.87	8485.8	7150.53	3736.77	5597.11
Total	116062.64	67770.82	72201.01	72534.5	75233.91	107995.08	77297.87	86542.8	63761.03	60347.27	76756.11
Grand total	482157.62	374723.41	353285.16	347778.82	330292.33	396810.41	316870.78	428895.65	285920.97	263308.2	354785.72
Yield q/ha 2013-16	3575	2700	2250	2400	2375	3000	2325	3075	1875	2175	2575
Productivity kg/MJ	0.69	0.72	0.63	0.69	0.71	0.75	0.73	0.71	0.65	0.82	0.72

4.10.1.1 Direct energy sources (MJ/ha)

During the study of direct energy sources from the selected area of Narsinghpur in 2013 to 2016. Shown in fig 4.20 and found that the farmers were used the human energy (15658.25 MJ/ha), animal energy (348.3 MJ/ha), diesel energy (36449.1 MJ/ha) and electrical energy (225573.96 MJ/ha). The percentage of direct energy sources like human, animal, diesel and electricity is varied as human (5.63%), animal (0.12%), diesel (13.10%) as well as electricity (83.13%) in the sugarcane cropping year from 2013 to 2016.

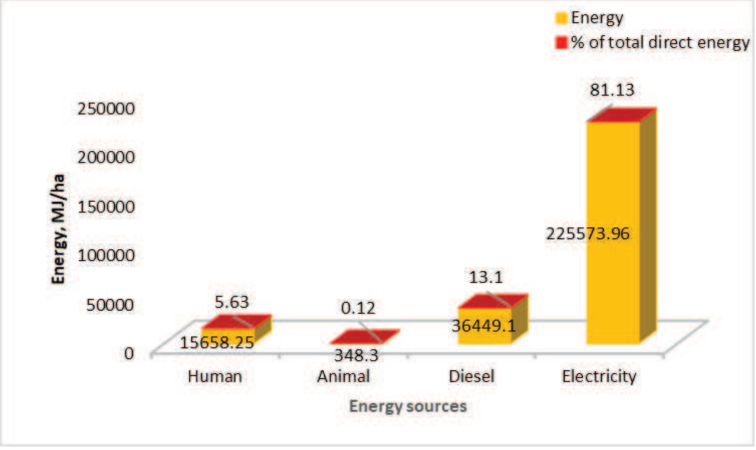

Fig 4.20 Direct energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.10.1.2 Indirect energy sources (MJ/ha)

During the study of direct energy sources from the selected area of Narsinghpur in from 2013 to 2016. Shown in fig 4.21 we found that the farmers were used indirect energy sources like; seed, fertilizer, chemical, FYM and Machinery energy sources. For seed energy (34497.5 MJ/ha), fertilizer energy (35509.2 MJ/ha), chemical energy (612.30 MJ/ha), FYM energy (540.00 MJ/ha) and machinery energy (5597.11 MJ/ha). The percentage of indirect energy sources like; seed, fertilizer, chemical, FYM and Machinery is varied as seed (44.94%), fertilizer (46.26%), chemical (0.79%), FYM

(0.70%) as well as machinery (7.29%) in the sugarcane cropping year from 2013 to 2016.

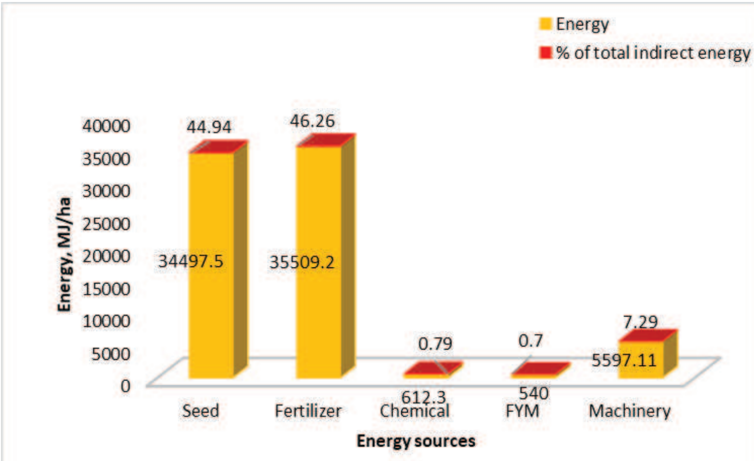

Fig 4.21 Indirect energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.10.2 Renewable- Nonrenewable energy ratio to productivity

Over the years of study, shown in table 4.12 there is an increased dependency on nonrenewable source of energy and reduction in renewable source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the renewable- nonrenewable ratio to the productivity from 0.69, 0.72, 0.63, 0.69, 0.71, 0.75, 0.73, 0.71, 0.65 and 0.82 in the year of 2013-16.

Table-4.12 Renewable energy sources and non-renewable energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Renewable energy sources (MJ/ha)											
Human	15842.46	13007.54	15085.79	15461.46	14974.89	27220.97	15062.6	14633.36	13025.98	12267.64	15658.25
Animal	-	1212	-	-	-	-	1818	-	453	-	348.3
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	34497.5
FYM	1800	-	-	900	-	1350	-	1350	-	-	540.00
Total	60042.46	50657.04	51523.29	53461.46	54724.89	68320.97	53980.6	55733.36	46603.98	45392.64	51044.05
Non-renewable energy sources (MJ/ha)											
Diesel	49885.02	39440.65	32379.36	26163.86	23153.53	27975.36	22447.41	77413.29	41810.16	23822.49	36449.1
Electricity	300367.5	253292.4	233619	233619	216930	233619	200244.9	250306.2	166870.8	166870.8	225573.96
Chemical	1614	-	450	540	909	1080	450	1080	-	-	612.30
Fertilizer	61200	25245	30045	29454	30369	61200	34731	35877	23485.5	23485.5	35509.2
Machinery	9048.64	6088.32	5268.51	4540.5	4205.91	4615.08	5016.87	8485.8	7150.53	3736.775597.11	
Total	422115.16	324066.37	301761.87	294317.36	275567.44	328489.44	262890.18	373162.29	239316.99	217915.56	303741.67
Grand total	482157.62	374723.41	353285.16	347778.82	330292.33	396810.41	316870.78	428895.65	285920.97	263308.2	354785.72
Yield q/ha 2013-16	3575	2700	2250	2400	2375	3000	2325	3075	1875	2175	2575
Productivity kg/MJ	0.69	0.72	0.63	0.69	0.71	0.75	0.73	0.71	0.65	0.82	0.72

4.10.2.1 Renewable energy sources (MJ/ha)

During the study of renewable energy sources from the selected area of Narsinghpur from 2013 to 2016. Shown in fig 4.22 we found that the farmers were used the human energy (15658.25 MJ/ha), animal energy (348.3 MJ/ha), seed energy (34497.5 MJ/ha) and FYM energy (540.00 MJ/ha). The percentage of renewable energy sources like human, animal, seed and FYM is varied as human (30.67%), animal (0.68%), seed (67.58%) as well as FYM (1.05%) in the sugarcane cropping year from 2013 to 2016.

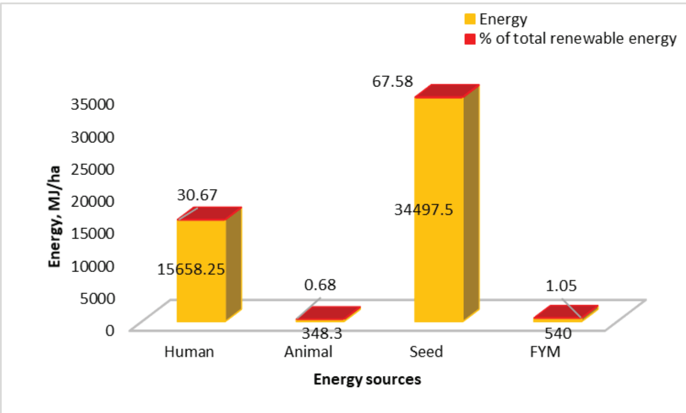

Fig 4.22 Renewable energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.10.2.2 Non-renewable energy sources (MJ/ha)

During the study of non-renewable energy sources from the selected area of Narsinghpur from 2013 to 2016. Shown in fig 4.23 we found that the farmers were used non-renewable energy sources like; diesel, electricity, chemical, fertilizer and machinery energy sources. For diesel energy (36449.10 MJ/ha), electricity energy (225573.96 MJ/ha), chemical energy (612.30 MJ/ha), fertilizer energy (35509.2 MJ/ha) and machinery energy (5597.11 MJ/ha). The percentage of non-renewable energy sources like; diesel, electricity, chemical, fertilizer and Machinery is varied as diesel

(12.00%), electricity (74.26%), chemical (0.20%), fertilizer (11.69%) as well as machinery (1.84%) in the sugarcane cropping year from 2013 to 2016.

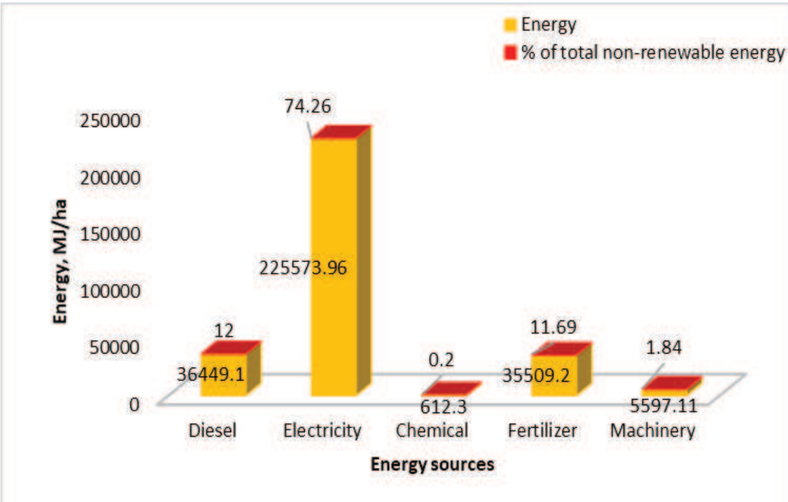

Fig 4.23 Non-renewable energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.10.3 Direct renewable- direct nonrenewable energy ratio to productivity

Over the years of study, sown in table 4.13 there is an increased dependency on Direct non-renewable source of energy and reduction in direct renewable source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the direct renewable-direct nonrenewable ratio to the productivity from 0.97, 0.87, 0.80, 0.87, 0.93, 1.03, 0.97, 0.89, 0.84 and 1.07 from the year of 2013 to 2016.

Table-4.13: Direct renewable or direct non-renewable energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Direct renewable energy sources (MJ/ha)											
Human	15842.46	13007.54	15085.79	15461.46	14974.89	27220.97	15062.6	14633.36	13025.98	12267.64	15658.25
Animal	-	1212	-	-	-	-	1818	-	453	-	348.3
Total	15842.46	14219.54	15085.79	15461.46	14974.89	27220.97	16880.6	14633.36	13478.98	12267.64	16006.65
Direct non-renewable energy sources (MJ/ha)											
Diesel	49885.02	39440.65	32379.36	26163.86	23153.53	27975.36	22447.41	77413.29	41810.16	23822.49	36449.1
Electricity	300367.5	253292.4	233619	233619	216930	233619	200244.9	250306.2	166870.8	166870.8	225573.96
Total	350252.52	292733.05	265998.36	259782.86	240083.53	261594.36	222692.31	327719.49	208680.96	190693.29	262023.06
Grand total	366094.98	306952.59	281084.15	275244.32	255058.42	288815.33	239572.91	342352.85	222159.94	202960.93	278029.71
Yield q/ha 2013-16	3575	2700	2250	2400	2375	3000	2325	3075	1875	2175	2575
Productivity kg/MJ	0.97	0.87	0.80	0.87	0.93	1.03	0.97	0.89	0.84	1.07	0.92

4.10.3.1 Direct renewable energy sources (MJ/ha)

During the study of direct renewable energy sources from the selected area of Narsinghpur from 2013 to 2016. Shown in fig 4.24 we found that the farmers were used the human energy (15658.25 MJ/ha) and animal energy (348.3 MJ/ha). The percentage of direct renewable energy sources like human and animal is varied as human (97.82%), animal (2.17%) in the sugarcane cropping year from 2013 to 2016.

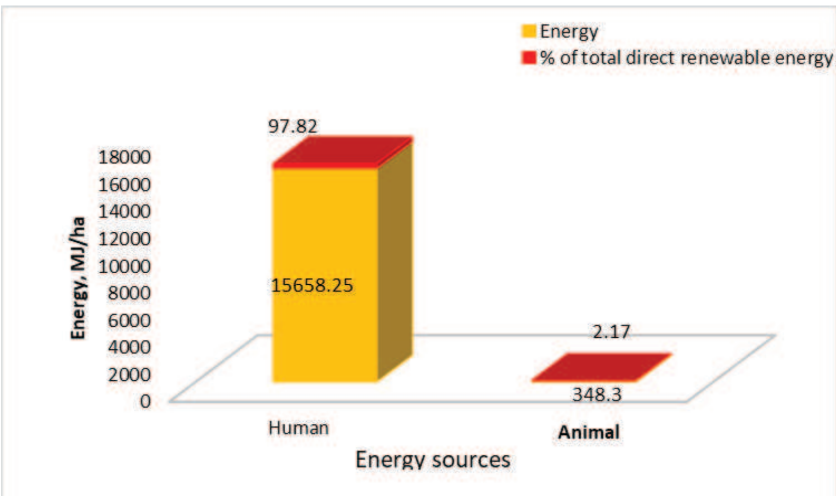

Fig 4.24 Direct renewable energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.10.3.2 Direct non-renewable energy sources (MJ/ha)

During the study of direct non-renewable energy sources from the selected area of Narsinghpur from 2013 to 2016. Shown in fig 4.25 we found that the farmers were used direct non-renewable energy sources like; diesel and electricity energy sources. For diesel energy (36449.10 MJ/ha) and electricity energy (225573.96 MJ/ha). The percentage of direct non-renewable energy sources like; diesel and electricity is varied

as diesel (13.93%) and electricity (86.08%) in the sugarcane cropping year from 2013 to 2016.

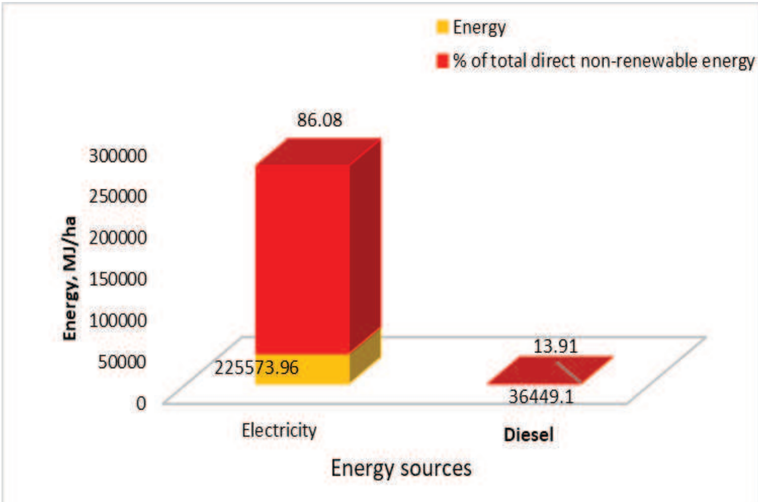

Fig 4.25 Direct non- renewable energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.10.4 Indirect renewable- indirect nonrenewable energy ratio to productivity

Over the years of study, shown in table 4.14 there is an increased dependency on indirect renewable source of energy and reduction in indirect non-renewable source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the indirect renewable-indirect nonrenewable ratio to the productivity from 3.08, 3.98, 3.11, 3.30, 3.15, 2.77, 3.00, 3.55, 2.94 and 3.60 from the year of 2013 to 2016.

Table-4.14 Indirect renewable energy and indirect non-renewable energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Indirect renewable energy sources (MJ/ha)											
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	34497.5
FYM	1800	-	-	900	-	1350	-	1350	-	-	540.00
Total	44200	36437.5	36437.5	38000	39750	41100	37100	41100	33125	33125	35037.5
Indirect non-renewable energy sources (MJ/ha)											
Chemical	1614	-	450	540	909	1080	450	1080	-	-	612.30
Fertilizer	61200	25245	30045	29454	30369	61200	34731	35877	23485.5	23485.5	35509.2
Machinery	9048.64	6088.32	5268.51	4540.5	4205.91	4615.08	5016.87	8485.8	7150.53	3736.77	5597.11
Total	71862.64	31333.32	35763.51	34534.5	35483.91	66895.08	40197.87	45442.8	30636.03	27222.27	41718.61
Grand total	116062.64	67770.82	72201.01	72534.5	75233.91	107995.08	77297.87	86542.8	63761.03	60347.27	76756.11
Yield q/ha 2013-16	3575	2700	2250	2400	2375	3000	2325	3075	1875	2175	2575
Productivity kg/MJ	3.08	3.98	3.11	3.30	3.15	2.77	3.00	3.55	2.94	3.60	3.35

4.10.4.1 Indirect renewable energy sources (MJ/ha)

During the study of indirect renewable energy sources shown in fig 4.26 it was found that the farmers used the seed energy (34497.5 MJ/ha) and FYM energy (540.00 MJ/ha). The percentage of indirect renewable energy sources like seed and FYM varied as seed (98.45%), FYM (1.54%) in the sugarcane cropping year from 2013 to 2016.

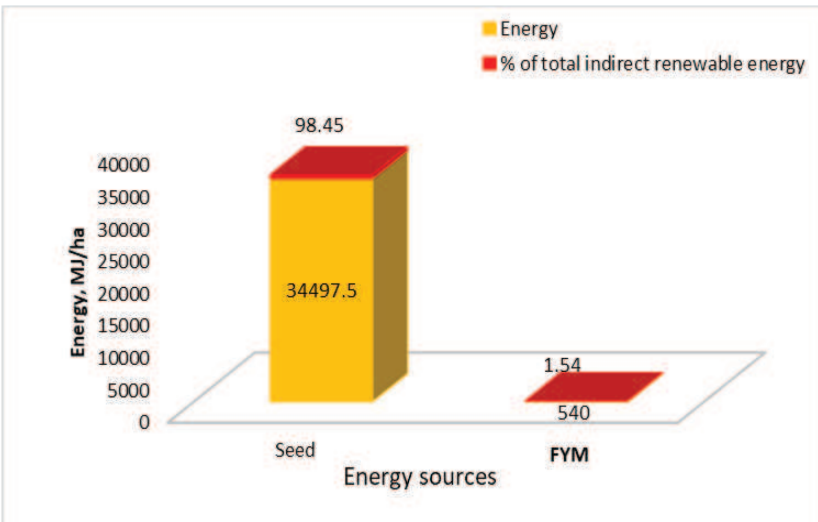

Fig 4.26 Indirect renewable energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.10.4.2 Indirect non-renewable energy sources (MJ/ha)

During the study of indirect non-renewable energy sources from the selected area of Narsinghpur from 2013 to 2016, shown in fig 4.27 it was found that the farmers used indirect non-renewable energy sources like; chemical, fertilizer and machinery energy sources. For chemical energy (612.30 MJ/ha), fertilizer energy (35509.2

MJ/ha) and machinery energy (5597.11 MJ/ha). The percentage of indirect non-renewable energy sources like; chemical, fertilizer and machinery varied as chemical (1.46%), fertilizer (85.11%) and machinery (13.41%) in the sugarcane cropping year from 2013 to 2016.

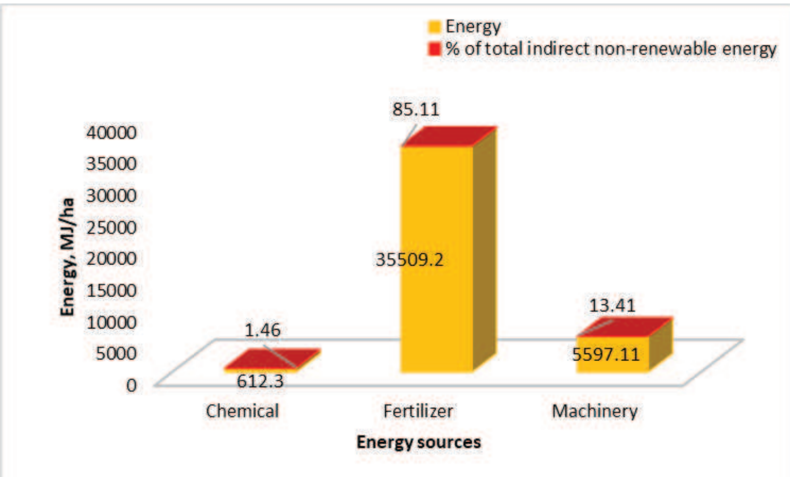

Fig 4.27 Indirect non-renewable energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.10.5 Commercial and non-commercial energy ratio to productivity

Over the years of study, shown in table 4.15 there is an increased dependency on commercial source of energy and reduction in non-commercial source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the commercial – noncommercial energy ratio to the productivity from 0.81, 0.79, 0.71, 0.77, 0.81, 0.84, 0.83, 0.79, 0.74 and 0.94 from the year of 2013 to 2016.

Table-4.15 Commercial or non-commercial energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Commercial energy sources (MJ/ha)											
Diesel	49885.02	39440.65	32379.36	26163.86	23153.53	27975.36	22447.41	77413.29	41810.16	23822.49	36449.1
Electricity	300367.5	253292.4	233619	233619	216930	233619	200244.9	250306.2	166870.8	166870.8	225573.96
Chemical	1614	-	450	540	909	1080	450	1080	-	-	612.30
Fertilizer	61200	25245	30045	29454	30369	61200	34731	35877	23485.5	23485.5	35509.2
Machinery	9048.64	6088.32	5268.51	4540.5	4205.91	4615.08	5016.87	8485.8	7150.53	3736.77	5597.11
Total	422115.16	324066.37	301761.87	294317.36	275567.44	328489.44	262890.18	373162.29	239316.99	217915.56	303741.67
Non- Commercial energy sources (MJ/ha)											
Human	15842.46	13007.54	15085.79	15461.46	14974.89	27220.97	15062.6	14633.36	13025.98	12267.64	15658.25
Animal	-	1212	-	-	-	-	1818	-	453	-	348.3
FYM	1800	-	-	900	-	1350	-	1350	-	-	540.00
Total	17642.46	14219.54	15085.79	16361.46	14974.89	28570.97	16880.6	15983.36	13478.98	12267.64	16546.55
Grand total	439757.62	338285.91	316847.66	310678.82	290542.33	357060.41	279770.78	389145.65	252795.97	230183.2	320288.22
Yield q/ha 2013-16	3575	2700	2250	2400	2375	3000	2325	3075	1875	2175	2575
Productivity kg/MJ	0.81	0.79	0.71	0.77	0.81	0.84	0.83	0.79	0.74	0.94	0.80

4.10.5.1 Commercial energy sources (MJ/ha)

During the study of commercial energy sources shown in fig 4.28 it was found that the farmers used the diesel energy (36449.10 MJ/ha), electricity energy (225573.96 MJ/ha), chemical energy (612.30 MJ/ha), fertilizer energy (35509.2 MJ/ha) and machinery energy (5597.11 MJ/ha). The percentage of commercial energy sources like; diesel, electricity, chemical, fertilizer and machinery varied as diesel (12.00%), electricity (74.26%), chemical (0.20%), fertilizer (11.69%) and machinery (1.84%) in the sugarcane cropping year from 2013 to 2016.

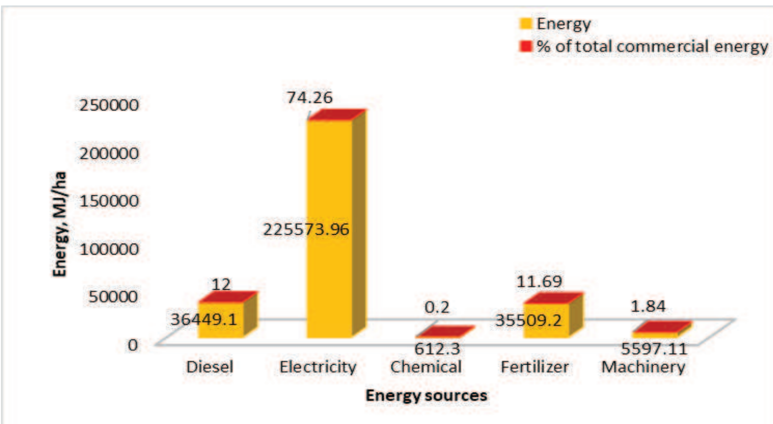

Fig 4.28 Commercial energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.10.5.2 Non-commercial energy sources (MJ/ha)

During the study of non-commercial energy sources shown in fig 4.29 it was found that the farmers used non-commercial energy sources like; human, animal and FYM energy sources. For human energy (15658.25 MJ/ha), animal energy (348.3 MJ/ha) and FYM energy (540.00 MJ/ha). The percentage of non-commercial energy sources like; human, animal and FYM varied as human (94.63%), animal (2.10%) and FYM (3.26%) in the sugarcane cropping year from 2013 to 2016.

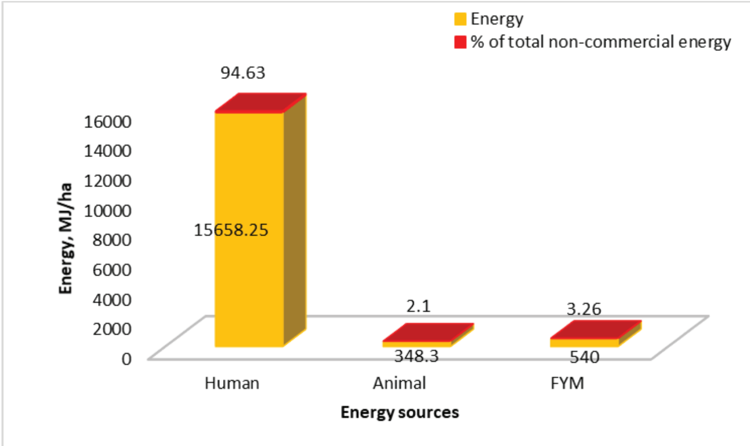

Fig 4.29 Non-commercial energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

4.11 Effect of seedbed preparation on yield

Effect of seedbed preparation on yield can be evaluated separately for selected area in different years of survey. The data of different round cannot be cumulated as productivity is affected by various parameters in a particular year including weather effect. The relationship is shown from year of 2013-16 (Effect is also discussed for the year 2013 to 2016).

4.11.1 Narsinghpur

The seedbed preparation energy consumption pattern for the year 2013-16 under tractor farming system shows that on an average the seedbed preparation energy consumption was 4607.47 MJ/ha. The tractor farming was more useful for sugarcane cultivation. The value for yield showed a great production on an average value of 10 farmers from the selected area was 2575 q/ha respectively. The higher productivity under tractor farming reveals that the farmers under this farming systems were from mainly Medium farm categories. These are the farmers who are not lacking as far as the physical inputs like fertilizers and water as well they had close look to their farming operations this resulted in to higher output-input energy ratio.

Fig 4.30 shows the relationship between seedbed preparation & yield for the facts as stated above in selected area Narsinghpur. Their relationship can be seen in the equation given below.

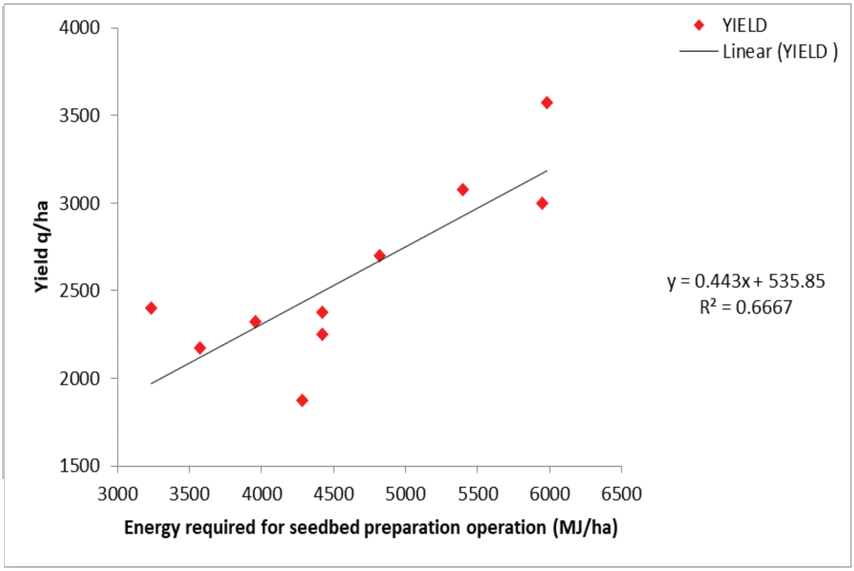

Fig. 4.30 Effect of seedbed preparation on yield of sugarcane (Narsinghpur, 2013-16)

$$y = 0.443x + 535.8 \qquad \text{.............eq.4.6}$$

$$(R^2 = 0.666)$$

Considering seedbed preparation as predictor and yield of sugarcane as response for all equations derived by statistical analysis using software “SPSS” and MS-Excel. Fig.4.30 presents the relationship for the year 2013-2016.

The relationship between yield &seedbed preparation energy is positive and direct. However statistically their relation is significant. Value of R^2 = 0.666.

4.12 Effect of sowing on yield

Effect of sowing on yield can be evaluated separately for selected area in different years of survey. The relationship is shown for year of 2013-16 (Effect is also discussed for the year 2013-16).

4.12.1 Narsinghpur

The sowing energy consumption pattern for the year 2013-16 under tractor farming system shows that on an average the sowing energy consumption was 38616.83 MJ/ha. The tractor farming was more useful for sugarcane cultivation. The value for yield showed a great production on an average value of 10 farmers from the selected area was 2575 q/ha respectively. The higher productivity under tractor farming reveals that the farmers under this farming systems were from mainly Medium farm categories. These are the farmers who are not lacking as far as the physical inputs like fertilizers and water as well they had close look to their farming operations this resulted in to higher output-input energy ratio.

Fig 4.31 shows the relationship between sowing & yield for the facts as stated above in selected area Narsinghpur. Their relationship can be seen in the equation given below.

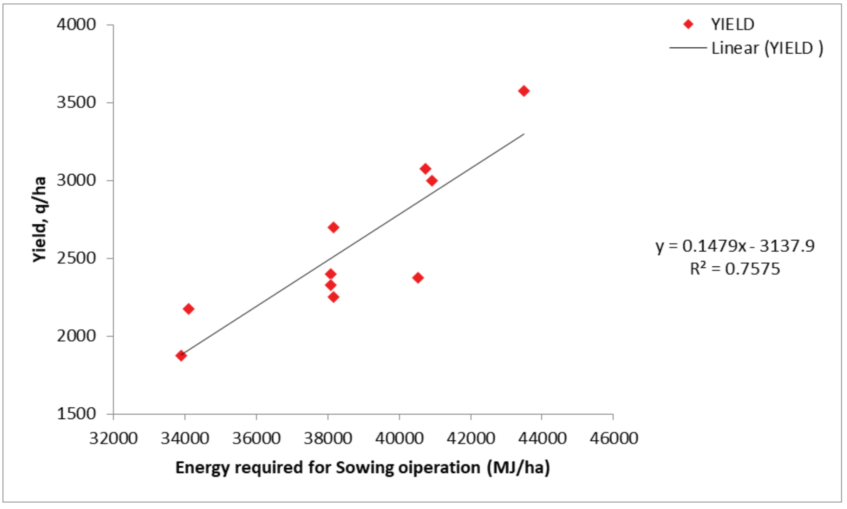

Fig. 4.31 Effect of sowing on yield of sugarcane (Narsinghpur, 2013-16)

$$y = 0.147x - 3137 \qquad \text{.......eq. 4.7}$$
$$(R^2 = 0.757)$$

Considering sowing as predictor and yield of sugarcane as response for all equations derived by statistical analysis using software "SPSS" and MS-Excel. Fig.4.31 presents the relationship for the year 2013-16.

The relationship between yield & sowing energy is positive and direct. However statistically their relation is significant. Value of $R^2 = 0.757$.

4.13 Effect of interculture on yield

Effect of interculture on yield can be evaluated separately for selected area in different years of survey. The relationship is shown for year of 2013-16 (Effect is also discussed for the year 2013-16).

4.13.1 Narsinghpur

In the year 2013-2016 it is observed that interculture required approximately 8084.88 MJ/ha under the tractor farming. Bullock farming is not considered as numbers of observation were low. The result approves the information derived from the selected area Narsinghpur. The yields under the bullock farming were 1875 q/ha as compare to 3575 q/ha under tractor farming. The output-input energy ratio was 1.73 and 2.00 for mix and tractor farming and their respective values for specific energy were 3.05 and 2.64 as stated earlier mix farmer used comparatively higher physical inputs like chemical fertilizer as compared to tractor farmers.

Fig 4.32 shows the relationship between interculture & yield for the facts as stated above in selected area Narsinghpur. Their relationship can be seen in the equation given below.

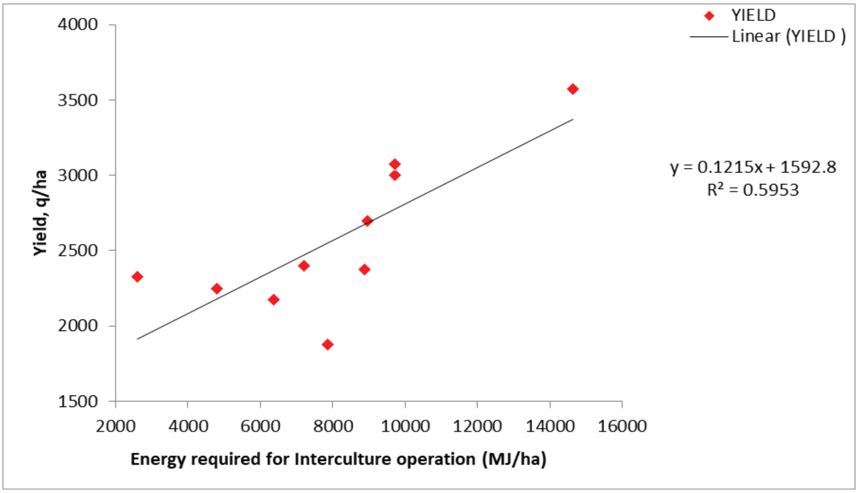

Fig. 4.32 Effect of interculture on yield of sugarcane (Narsinghpur, 2013-16)

Looking to fig 4.32 and equation derived to show the relationship among interculture energy use and productivity in the Narsinghpur for the year 2013-16 it can be said that there is a great effect of level of interculture on the yield of sugarcane in the Narsinghpur. There exist great scopes to enhance the yield by increasing Interculture. The relationship is strong and positive.

$$y = 0.121x + 1592 \qquad \text{......eq. 4.8}$$
$$(R^2 = 0.595)$$

Considering interculture as predictor and yield of sugarcane as response for all equations derived by statistical analysis using software “SPSS” and MS-Excel. Fig.4.32 presents the relationship for the year 2013-16.

The relationship between yield & interculture energy is positive and direct. However statistically their relation is significant. Value of R^2 = 0.595.

4.14 Effect of irrigation on the yield of sugarcane

The relationship between yield and irrigation energy is mainly considered for the year 2013-16. The effect of irrigation for the selected area Narsinghpur can be detailed as below

4.14.1 Narsinghpur

The crop sugarcane was grown by the farmers after paddy crop. It is also cultivated by the farmers had fellow land during kharif. In Narsinghpur "Havelli" system was used in which rainfall water is stored during rainy season. In this system land used to be sloppy at the center like ponds so water do not loss by runoff. In the Narsinghpur most of the farmers possessed tube well and the farmers, who did not have water source, hired the irrigation water from neighboring farms. The relation between irrigation energy and yield is shown in fig 4.33 for the selected area Narsinghpur. By considering irrigation energy as predictor and yield as response they can be co-related with the following equation.

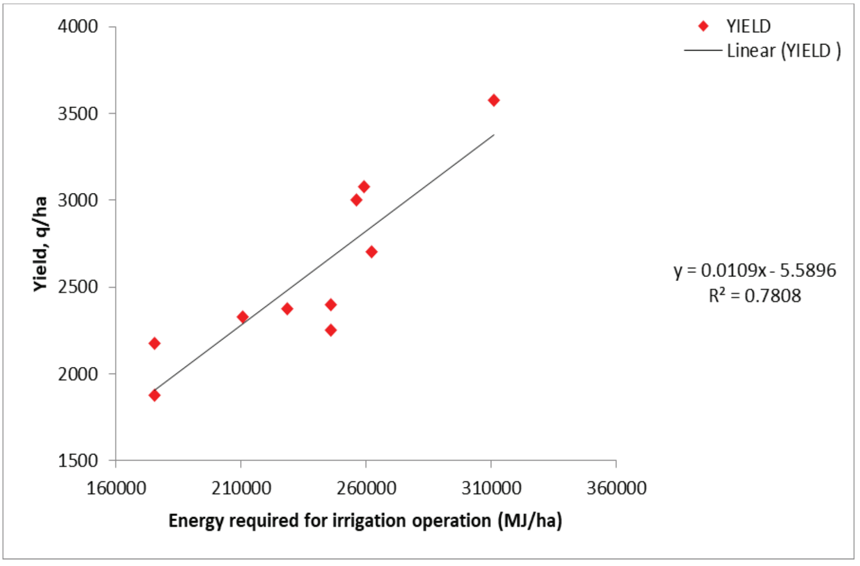

Fig. 4.33 Effect of irrigation on the yield of sugarcane (Narsinghpur, 2013-16)

$$y = 0.010x - 5.589 \qquad \text{………..eq. 4.9}$$

$$(R^2 = 0.780)$$

Higher irrigation energy means either higher number of irrigation or more hours of water supply in each irrigation. In these years the water reached to the plants by free flow. Most of the farms had slope for movement of the water. The variation in irrigation energy was too much and there were few farmers who did not apply any irrigation and totally dependent on winter or summer rains. The results revealed that un-irrigated fields average yield was only 1875 q/ha which was less than half of the average yield in the selected area of Narsinghpur. The choice of sugarcane crop by the farmers has been based on availability of assured irrigation. The farmers without assured irrigation did not inclined to select sugarcane crop rather they selected other crop like; wheat, urid, black gram, green gram etc. These relations were found stronger when the data of farmers survey of the years from 2013 to 2016 was considered.

Fig 4.33 shows irrigation level is one of the most effective factors to enhance yield of sugarcane in the Narsinghpur. The data of the year 2013-16 of the selected area Narsinghpur shows that there exists strong and positive co-relation between energy consumption for irrigation and productivity of sugarcane. They are significantly co-related at 1 per cent level of significance. The value of R^2 is 0.780.

4.15 Effect of Fertilizer energy on the yield of sugarcane

There are number of inputs which are essential for the production of sugarcane out of all the physical inputs the fertilizers gave comparatively higher impact in production agriculture. Therefore, it has become essential to discuss the effect of fertilizer on the yield of sugarcane in the selected area for survey.

4.15.1 Narsinghpur

From the year 2013 to 2016 except 8 farmers all have applied chemical fertilizer. Approximate yield of 1875 q/ha was observed for the farmers who did not use fertilizer in proper quantity. On the other hand the use of fertilizer energy varied to a great extent and the value of fertilizer energy varied between 23485.5 MJ/ha to 61200 MJ/ha in the year 2013 to 2016. Whereas the corresponding value

of yield of sugarcane was 1875 q/ha and 3575 Q/ha. Fig 4.34 Shows the relationship and can be expressed mathematically as.

$$y = 0.029x + 1536 \qquad \text{..........eq.4.10}$$
$$(R^2 = 0.660)$$

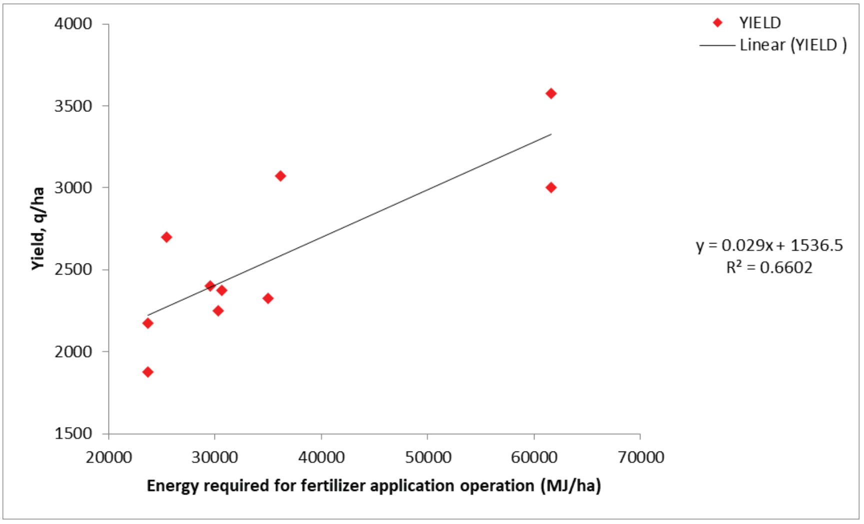

Fig. 4.34 Effect of fertilizer on the yield of sugarcane (Narsinghpur, 2013-16)

It means higher yield can be obtained by increasing use of agro fertilizer in the selected area Narsinghpur (fig 4.34). Looking to the effect at individual farmers field. The energy from fertilizer was minimum of 23485.5 MJ/ha and maximum of 61200 MJ/ha the corresponding yield was 1875 q/ha and 3575 q/ha**.**

Fig 4.34 clearly speaks that higher the application of chemical fertilizer energy more will be the production of sugarcane in Narsinghpur. It is mainly due to the reason that farmers are still far away from the recommended dose of fertilizer. But they realized the importance of chemical fertilizer and the energy contribution by fertilizer increased to about certain limit (61623 MJ/ha) the quantity of fertilizer

application almost stagnant. The application of FYM reduced abruptly during the last decade. This is one reason to increase use of fertilizer to increased yield.

From the figure it can be concluded that there needs to be the intensive use of fertilizer for the production of sugarcane in the Narsinghpur as in the year of 2013 to 2016 there existed a positive and strong co-relation between application of energy through fertilizer and productivity of sugarcane.

SUMMARY, CONCLUSIONS & SUGGESTIONS FOR FUTURE WORK

5.1 Summary

Energy is the key for development and judgment of developed and developing countries can be made on the basis of per capita energy consumption. Energy consumption in developed countries is very high as compared to developing countries. It is the need of hour to use energy carefully and plug all wasteful uses of energy in agricultural production system. The introduction of high yielding varieties of crops in early seventies and progressive expansion of area under these varieties created an increasing demand of energy inputs. However, worldwide reports from intensive agricultural production system have indicated that there is an increasing trend in production with increase in energy use upto certain limit. But after that law of diminishing return starts operating at a certain level of energy inputs reducing the energy efficiency of production. Oil energy is being used not only in the form of fuel for operating machinery in production agriculture but also indirectly in the production of variety of materials, specially fertilizers. Also use of high yielding varieties demanding high energy for irrigation, fertilizer and pesticide have led to negative environmental effects which ultimately would require additional energy and economic inputs for regeneration. The most distributing feature is that agriculture has been proved to be unsustainable in the long run giving lesser yield with time for the same level of inputs due to a variety of reasons including development of soil salinity, soil erosion etc.

The above scenario of early seventies spurred a number of research groups to consider the energy and environment issues in depth in the light of achieving sustainable agriculture. There is a wide variation in the energy consumption pattern with crops, geo-climatic variations and cultural practices. Due to this, studies have to be location specific.

Sugarcane is found to be one of the most important *rabi/kharif* crop of the state. Most farmers having assured irrigation adopt the sugarcane cultivation. The area under Sugarcane increased from 49.70 thousand hectares in 2011-12 to 73.10 thousand hectare in 2013-14 and 103 thousand hectare is 2015-16 with the average yield of 21351.2 kg/ha.

The level of productivity depends upon level of energy inputs applied on different farm operations. The trend of use of direct energy resources have been dynamic in the state with the major shift to non renewable and commercial sources as electricity, fertilizer, and diesel; it has become imperative to ensure timely and adequate supply of these resources so, that energy investments made are fully exploited.

The present study deals with the energy audit and energy optimization. Energy audit includes the study related to energy use pattern, farm power availability, changing energy scenario, energy requirement for different operations, and energy utilization from different direct and indirect energy sources. Under optimization relationship is established between yield of sugarcane and different operation level and input energy with the help of curves, equations and statistical analysis are used to predict the energy requirement for different operation through different source to achieve the required yield within the potential limit.

5.2 Conclusions

1. The contributions of seed energy were varied from minimum 33125 MJ/ha to maximum 42400 MJ/ha during the 3 years cropping session from 2013 to 2016 in sugarcane crop production in the selected area of Narsinghpur, Madhya Pradesh.
2. The use of total energy was highest in tractor farms followed by the animal farms for sugarcane cultivation, tractor farms were followed by animal farms.
3. The energy productivity ranged from 0.25 kg/MJ to 0.35 kg/MJ in 2013-14, 0.41 kg/MJ to 0.53 kg/MJ in 2014-15 and 0.30 kg/MJ to 0.41 kg/MJ in 2015-16 for sugarcane crop.
4. The average yield of sugarcane is varied from 895 Q/ha in 2013-14, 955 q/ha in 2014-15, 725 q/ha in 2015-16 and the total average output yield 2575 q/ha during 2013 to 2016.
5. The fertilizer was energy consuming source for the sugarcane which consumed about 10 % of total source wise energy input from 2013 to 2016 in Narsinghpur for the better production of sugarcane.

6. Irrigation was found to be the highest energy consuming operation across selected area under study. Specifically, it consumed about 79056.13 MJ/ha in 2013 and 237168.39 MJ/ha during 2013 to 2016 for the selected area Narsinghpur. Among various operations, irrigation, consumed maximum energy ranged between 51 to 63 per cent while considering the reference year 2013-14.

7. The maximum use of diesel energy occurred in tractor farms which accounted for energy consumption 15211.46 MJ/ha in 2013-14 and 10618.82 MJ/ha in 2015-16 or the total diesel energy consumed 36449.1 MJ/ha during 2013 to 2016.

8. On an average the tillage consumption was 4607.47 MJ/ha for mix farming the corresponding yield was 2575 q/ha in 2013-14 respectively. Hence, there is a direct co-relation between tillage energy consumption, bullock and tractor farming.

9. The use of direct energy was comparatively very high as compared to indirect energy in early surveys. The direct-indirect energy ratio was 3.62 from the total energy input from 2013 to 2016 in Narsinghpur for sugarcane.

10. The use of renewable to non-renewable was decreased from the direct or indirect energy sources. The energy ratio between renewable or non-renewable energy sources was 0.16 during the cropping session from 2013 to 2016. The reason being the reduced use of animate power.

11. With the year pass the use of commercial energy increased and on the other and non-commercial energy use decreased. This resulted into higher energy ratio was found. The commercial or non-commercial energy ratio was 18.35 during the year of 2013 to 2016.

12. Better management of physical inputs, timeliness of operations, saving in unnecessary tillage, quality seed, use of superior chemicals for plant protection, uniformity of water use resulted into a great positive effect which can be seen by output-input energy ratio and yield for the production of sugarcane in Narsinghpur. The energy ratio was 6.86 during 2013 to 2016.

13. Optimization of energy inputs are done on the basis that with application of zero inputs in the field the production will be zero. To make the unique uniformity in independent variables (inputs) the quantity or level is converted in to energy. For evaluating the effect of field operation, the relationship between yield and tillage energy. In the opted optimization technique, the relationship between dependent variable (yield) and independent variable (tillage energy, irrigation energy etc.) are developed by drawing the curve between variables for individual farms. Curves are drawn mainly for the data of 2013-14 and 2013 -16. Different equations are derived for different energy inputs and yield. The effect of farming system is discussed only for the year 2013.

14. The use of total operational energy ranged from 112935.73 MJ/ha to 193041.69 MJ/ha in 2013-14, 75112.64 MJ/ha to 143363.5 MJ/ha in 2015-16 and 263455.01 MJ/ha to 480161.18 MJ/ha from the total operation wise energy input from 2013 -16 for sugarcane production in Narsinghpur.

15. The growth rate of sugarcane crop was highly significant compared to other crop in Narsinghpur.

5.3 Suggestions for future work

1. The work should be continued with data from more villages/areas growing sugarcane crop.
2. The similar work should be carried out in these lines for other important crops of the Narsinghpur i.e, wheat, paddy, soybean, gram etc. for better energy planning.
3. The prediction of yield and energy inputs can also be done by more precise mathematical techniques.

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APPENDIX

Appendix 1

Proforma for data collection from farmer's Field

1) Information of the farmers:

a) Name of the farmer:…………………………………..S/O…………………………

b) Contact Number……:……………………………………........

c) Total cultivated area in (acre):……………………………………………

d) Total area under cultivation of sugarcane crop in (acre):……………………

e) Total area under cultivation of rabi crop in (acre):…………………………………

f) Total area under cultivation of kharif crop in (acre):………………………

g) Crop growing year of sugarcane : …………… …………… …..…………

h) Source of irrigation :

Power source in hp :………………

i) Tubewell :……………… Irrigated Area in (acre) :………………………

ii) Canal :…………………. Irrigated Area in (acre):……………………….

iii) Open well :…………..... Irrigated Area in (acre) :………………………

iv) Nalah :………………… Irrigated Area in (acre) :………………………

v) Other :…………………. Irrigated Area in (acre) :…………………………

i) Total irrigated area in (acre) :………………………………………………

j) Other information of farmers land :

A) Land owned, (acre) :Upland ……… Midland………… Lowland…………

B) Land leased in, (acre) : Upland ……… Midland………… Lowland…………

C) Land leased out, (acre): Upland ………Midland………… Lowland………

2) Use of HYV seeds, Fertilizers and other improved technology:

(a)Variety of seeds …………………Quantity/Acre ………………..Price/q………………

……………… Quantity/Acre ……………….. Price/q………………

(b)Fertilizer …………………. Quantity/Acre …………………Price/q………………

…………………. Quantity/Acre ………………... Price/q………………

…………………. Quantity/Acre ………………... Price/q………………

3) Farm equipments:

	Bullocks (Quality)	Tractor (hp)	Tractor-trolley (Size of trolley)	Planter/Harvester (hp of machine)	Pump set (hp of pump)
Own	……………..	………	…………………..	……………………	…………..
On hire	……………	..………	…………………..	……………………	..…………

4) Home technology: (Number/Size)

Biogas Plant (Size)	Improved choolah (Number)	Radio (Number)	TV (Number)	Motorcycle, scooter/Car (Number)
……………...	……………………...	…………..	…………	…………………..

Gas(LPG) (Number)	Mobile (Number)
…………...	…………..

Tubewell (Depth of water level &hp of motor) ………………………………

5) Detail of Seed :

Name of Seed	Variety of seed	Quality of seed	Quantity of seed In q/(acre)	Production in Ton/acre
Sugarcane				1st yr-
				2nd yr-
				3rd yr-

6) Operations of field preparation for sugarcane crop:

(i) First operation:

(a) Source of power:-

Tractor (hp) :…………………….

Animal :………………………….

(b) Machinery:-

M.B plough/Cultivator/Rotavator :…………………

Bullock drawn harrow :………………

Tractor drawn harrow :………………

Other :………………………………….

Total area covered by the operation :……………………………….

(ii) Second operation:

(a) Source of power:-

Tractor (hp) :…………………….

Animal :………………………….

(b) Machinery:-

M.B plough/Cultivator/Rotavator :…………………

Bullock drawn harrow :………………

Tractor drawn harrow :………………

Other :…………………………………

Total area covered by the operation :……………………………….

(iii) Third orperation:

(a) Source of power:-

Tractor (hp) :…………………….

Animal :………………………….

(b) Machinery:-

M.B plough/Cultivator/Rotavator/Bund former :…………………

Bullock drawn harrow :………………

Tractor drawn harrow :………………

Other :………………………………..

Total area covered by the operation :……………………………….

7) Field preparation of sugarcane crop:

Plough (Size)		Cultivator (Size)	Harrow (Size)		Disk Harrow (Size)	Blade harrow (Size)	Rigger (Size)	Roto-Vator (Size)	Land leveler (Size)	Bund former (Size)	
Reve-Rsible	Non-reversible		Animal Drawn	Tractor Drawn						Animal drawn	Tractor drawn

Tractor operating (hr) :………………………………….. hp of tractor :………………

Animal working (hr) :……………………………………..

Man/women working (hr) :……………………………

Pump operating (hr) :…………………………………. hp of pump :…………………

Power source of pump:

(a) Electric :…………

(b) Diesel :……………..

8) Detail of power source:

Type	Make	Model	Power ratting	Year of purchase	Price
Tractor					
Power tiller					
Electric pump					
Diesel pump					
Electric motor					
Any other sources					

9) Cropping pattern:

Crop season		Area, acre		Input used, kg/acre				Chemical used		Yield, kg/acre	
		Doses	acre		Fertilizer used					main	by-product
	Crops grown			Seed	Urea	DAP	MOP	Insecticides	Weedicides		
Kharif		1st Dose									
		2nd Dose									
		3rd Dose									
Rabi		1st Dose									
		2nd Dose									
		3rd Dose									
Summer											

10) Problem faced by farmer
:..
....
....

11) Production Normal or Not reason:
....
....
....
....

Date: ……./……./……….

……………………………………

Signature of the farmer

12) Self assessment :

Sr. No.	Source	Operation					
		Planting Of Sugarcane	Interculture	Irrigation	Harvesting	Transportation	Ratooning
1.	Labour (hr)						
2.	Tractor (hr)						
3.	Diesel Engine (hr)						
4.	Electric Motor (hr)						
5.	Planter (hr)						
6.	Harvester (hr)						

Appendix 2

Energy equivalents

Particulars	Unit	Equivalent	Remarks
Human labour			
Adult men	Man-h	1.96	1.96
Women	Woman-h	1.57	1 adult woman=0.8 adult man
Children	Child-h	0.98	1 child = 0.5 adult man
Animals			
Bullocks			
Large	Pair-h	14.05	Body weight above 450 kg
Medium	-do-	10.10	Body weight above 350-450 kg
Small	-do-	.07	Body weight less than 350 kg
He-buffalo	-do-	15.15	He –buffalo=1.5 medium bullocks
Camel/horse	Animal-h	10.10	Camel/horse=medium bullocks pair
Mules & other Small Animal	-do-	4.04	Small animal=0.4 medium bullock Pair
Diesel	Liter	56.31	Include cost of lubricants
Petrol	Liter	48.23	-do-
Kerosene	Liter	43.00	
Electricity	kWh	11.93	
Machinery			
Electric motor	Kg	64.8	Distribute the weight of the machinery equally over the total life of the machine in hours.
Prime movers	Kg	58.4	
Farm machinery	Kg	62.7	
Chemical fertilizer			
Nitrogen	Kg	60.0	Estimate the quantity of nitrogen, P2O5, K20 in fertilizer and compute the energy input
Phosphorus	Kg	11.1	Kg
Potash	Kg	6.7	Dry matter basis
Chemicals			
Superior	Kg/1	120.0	Chemical requiring dilution
Inferior	Kg/1	10.1	DDT,Gypsum or any other chemical not Requiring dilution
Zinc sulphate	Kg	20.9	
Dung	Kg	18.0	Dry matter dung cakes
Fire wood	Kg	18.0	-do-
Agriculture waste	Kg	18.0	-do-

Energy coefficient of various equipment (MJ/h)

Power source	Equipment	Energy coefficient, MJ/H
Mannual	Khurpa	0.031
	Kasola	0.188
	Spade	0.314
	Spickle	0.031
	Sickle	0.836
	Bund former	0.502
	Sprayer	0.502
	Wheel hand hoe	0.502
		0.314
Animal	Plough	0.627
	Cultivator	1.881
	Disc harrow	3.135
	Planter	1.568
	Seed drill/planter	1.254
	Puddler	1.254
	Bund former	1.442
	Cart	5.204
	Toka	1.129
	Straw combine	35.112
Tractor	M.B.Plough	2.508
	Cultivator	3.135
	Disc plough	3.762
	Planter	9.405
	Disc harrow	7.336
	Seed/planter	8.653
	Leveller	4.703
	Bund former	2.063
	Rotavator	10.283
	Puddler	2.508
	Combine	47.025
	Trailer	17.431
	Reaper	5.5176
Others	Thresher/sheller	7.524
	Power toka	1.568
	Cane crasher	1.768
	Centrifugal pump	1.750
	Self propelled combine	171.000
	Tractor ford 45 hp & above	16.416
	Tractor (other)	10.944
	Electric motor 35 hp	0.343
	Electric motor (other)	0.216
	Diesel engine	0.581

Appendix 3

Improved package of practice for sugarcane cultivation:

1- Seed bed preparation	T.D. M.B. plough x1, T.D. Rotavator x1, T.D. Cultivator x1, T.D. Bund Former x1
2- Sowing	T.D. Sugarcane planter, Manually
3- Interculture	B.D. plough x(1-2), T.D. Cultivator x3, T.D. Rotavator x(1-2)
4- Irrigation	Electric motor/pump
5- Fertilizer application	Manually x3
6- FYM application	Tractor trolley + Manually
7- Plant protection	Manually + Knapsack sprayer x3
8- Harvesting	Manually
9- Transportation	Tractor Trolley
10- Ratooning	Manually

The value of load coefficient factor (LCF) and Specific fuel consumption (SFC)for various power sources and type of work

S. No.	Power source	Type of work	LFC	SFC (ml/kW/h)	SFC (ml/hp/h)
1.	Stationery	Water lifting	0.6	295	220
2.	Diesel engine		0.8	295	220
3.	Tractor	Light work, e.g. transport, water-Lifting, etc.	0.4	282	210
		Medium work, e.g. secondary Tillage, sowing, inter-culture, Etc.	0.5	282	210
		Heavy work, e.g. Primary tillage, Harvesting, etc.	0.6	282	210
4.	Self-propelled machine	Harvesting, etc.	0.7	282	210
5.	Small petrol engine	Spraying, dusting, etc.	0.8	671	500

Formula are using in energy calculation in MJ/ha :

1) For man/women = No. of working hr x energy equivalent (man/women)

2) For Bullock pair = No of working hr x energy equivalent (B.P.)

3) For Diesel $= \frac{\mathrm{LCF} \times \mathrm{RHP} \times \mathrm{SFC} \times \mathrm{No.\ of\ working\ hr}}{1000}$

Where:

LCF = Load coefficient factor

RHP = Rated horse power (hp)

SFC = Specific fuel consumption

4) For Machinery :

$$a)\ For\ trcator = \frac{\mathrm{E.e.\ of\ tractor} \times \mathrm{No\ of\ working\ hr} \times \mathrm{wt\ of\ tractor\ (kg)}}{\mathrm{Life\ of\ tractor(hr)}}$$

Where, E.e. = Energy equivalent

$$\mathrm{b)\ For\ machinery} = \frac{\mathrm{E.e.\ of\ Machine} \times \mathrm{No\ of\ working\ hr} \times \mathrm{wt\ of\ Machine\ (kg)}}{\mathrm{Life\ of\ Machine(hr)}}$$

c) Total machinery energy in MJ/ha = (a+b)

5) For fertilizer $= \frac{\mathrm{Amount\ of\ fertilizer\ (kg)} \times \%\ \mathrm{of\ content}}{100} \times \mathrm{Energy\ eq.}$

6) For seed = Quantity of seed (Kg/ha) x energy eq. of seed.

7) For Chemical = Quantity of chemical x energy eq. of chemical.

Appendix 4

All India state wise area coverage and yield estimate of sugarcane during 2013-2016.

Name of state	2013-14			2014-15			2015-16		
	Area (000ha)	produ-ction (000 t)	Yield (t/ha)	Area (000ha)	produ-ction (000 t)	Yield (t/ha)	Area (000ha)	produ-ction (000t)	Yield (t/ha)
Madhya Pradesh	73	3173	43.47	111	4567	41.14	73	3343	45.79
Andhra Pradesh	192	15385	80.13	177	13150	74.29	157	12460	79.36
Tamil Nadu	313	32454	103.69	263	24463	93.02	263	27615	105.0
Gujrat	174	12550	72.13	204	14060	68.92	185	13040	70.49
Punjab	89	6675	75.00	94	7039	74.88	99	7131	72.03
Uttar Pradesh	2228	134689	60.45	2228	138481	62.15	2116	133203	62.95
India	4993	352141	70.53	5144	359330	69.85	4918	341425	69.42

Source:- Indian institute of sugarcane research institute Lucknow/database

Appendix 5

Production, yield and area of Sugarcane in Madhya Pradesh

Year	Area 000’ ha	Production 000’	Yield kg/ha
2011-12	49.70	196.80	3971
2012-13	54.10	276.00	5114
2013-14	73.10	361.30	4946
2014-15	111	457	41153
2015-16	103	528	51272

Appendix 6

Detail about Life or weight of machineries

Sr. No.	Name of machine	Weight (Kg)	Life (Hr)
1.	Cultivator	500	4000
2.	Rotavator	500	2400
3.	Bund former	250	1500
4.	Planter	500	2000
5.	Electric motor	63	10000
6.	Knapsack sprayer	5	5000
7.	M.B. plough (Non-reversible)	150	3000
8.	M.B. plough (reversible)	250	3000
9.	Tractor	2000	10000
10.	Trolley	1500	3600
11.	Disc harrow	500	3000
12.	Diesel engine (5hp)	110	10000
13.	Country Plough	25	3000

Appendix 7

Details of population like male or female in Narsinghpur:

Sr. No.	Particular	Narsinghpur district
1.	Geographical area (sq. K.M.)	513651
2.	Population-	1092141
	Male	567913
	Female	524228
3.	Literacy level (overall)-	77.12 percent
	Male	73465
	Female	147716
4.	Sex ratio per thousand males	910
5.	No. of Tehisils	05
6.	No. of Gram Panchayat	457
7.	No. of Zanpad Panchayat	06
8.	No. of villages	1052

Appendix 8

Operation wise or source wise energy (MJ/ha) used in Narsinghpur district of Madhya Pradesh in 2013-14.

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Operation wise energy (MJ/ha)											
Seedbed Pre.	5984.33	4818.04	4420.33	3233.72	4420.33	5953.09	3957.49	5396.2	4280.10	3571.09	4607.47
Sowing	43497.6	38153.6	38153.14	38080	40534	40926	38080	40730	33909	34105	38616.83
Interculture	4882.19	2987.39	1603.84	2405.76	2963.23	3241.96	872.45	3241.96	2623.87	2127.03	2694.96
Irrigation	103673.9	87390.31	82016.31	82016.31	76157.36	85446.31	70299.71	86394.8	58583.11	58583.11	79056.13
Fertilizer Appli	20541	8494	10094	9865	10211	20541	11665	12047	7899	7899	11925.5
FYM Appli.	2071.03	-	-	1005.43	-	1426.46	-	1186.79	-	-	568.97
Plant prot.	614.48	-	309.38	260.98	314.76	512.8	230.9	512.8	-	-	275.61
Harvesting	1176	1176	1097	980	1176	1176	980	1176	980	980	1089.70
Transportation	10405.15	10405.15	8344.95	5523.50	4185.58	4185.58	7432.17	22916.61	12386.94	5523.50	9130.91
Ratooning	196	196	156.80	147	156.80	156.80	196	156.80	156	147	166.52
Total	193041.69	153620.93	146195.75	143517.7	140119.26	163575	133713.72	173768	120818	112935.73	148130.6
Source wise energy (MJ/ha)											
Human	6096.4	4469.78	5147.83	5869.22	5584.53	9927.89	5752.6	5599.72	4936.26	4807.88	5819.21
Animal	-	404	-	-	-	-	606	-	151	-	116.10
Diesel	20395.48	17141.89	14540.36	10703.4	10443.25	13072.36	9960.11	29210.81	16538.24	10108.77	15211.46
Electricity	100122.5	84430.8	77873	77873	72310	77873	66748.3	83435.4	55623.6	55623.6	75191.32
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	37497.50
Fertilizer	20400	8415	10015	9818	10123	20400	11577	11959	7828.5	7828.5	11836.40
FYM	600	-	-	300	-	450	-	450	-	-	180.00
Chemical	538	-	150	180	303	360	150	360	-	-	204.10
Machinery	2491.45	2321.96	2032.95	1674.14	1605.49	1741.88	1819.91	3003.36	2615.79	1442.05	2074.89
Total	193041.69	153620.93	146195.64	143517.7	140119.26	163575.11	133713.72	173768	120818	112935.73	148130.6
Grand total	386083.38	307241.86	292391.39	287035.4	280238.52	327150.11	267427.44	347536	241636	225871.46	296261.2
Yield q/ha 2013-14	1375	950	750	750	875	1125	750	1000	625	750	895.00
Energy ratio	1.88	1.63	1.35	1.38	1.65	1.82	1.48	1.52	1.37	1.75	1.60
Specific energy MJ/kg	2.80	3.23	3.89	3.82	3.20	2.90	3.56	3.47	3.86	3.01	3.31
Productivity kg/MJ	0.35	0.30	0.25	0.26	0.31	0.34	0.28	0.28	0.25	0.33	0.30

Appendix 9

Total operation wise or source wise energy (MJ/ha) used in Narsinghpur district of Madhya Pradesh in 2013-16.

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Average
Operation wise energy (MJ/ha)											
Seedbed Pre.	5984.33	4818.04	4420.33	3233.72	4420.33	5953.09	3957.49	5396.2	4280.10	3571.09	4607.47
Sowing	43497.6	38153.6	38153.14	38080	40534	40926	38080	40730	33909	34105	38616.83
Interculture	14646.57	8962.17	4811.52	7217.28	8889.69	9725.88	2616	9725.88	7871.61	6381.09	8084.88
Irrigation	311021.7	262170.93	246048.93	246048.93	228472.08	256338.93	210899.13	259184.4	175749.33	175749.33	237168.39
Fertilizer Appli	61623	25482	30282	29595	30633	61623	34995	36141	23697	23697	35776.5
FYM Appli.	6213.09	-	-	3016.29	-	4279.38	-	3560.37	-	-	1706.91
Plant prot.	1843.44	-	928.14	782.91	944.28	1538.4	692.7	1538.4	-	-	826.83
Harvesting	3528	3528	3291	2940	3528	3528	2940	3528	2940	2940	3269.1
Transportation	31215.45	31215.45	25034.85	16570.5	12556.74	12556.74	22296.51	68749.83	37160.82	16570.5	27392.73
Ratooning	588	588	470.4	441	470.4	470.4	588	470.4	468	441	499.56
Total	480161.18	374918.19	353440.85	347925.63	330448.52	396939.82	317064.83	429024.48	286075.86	263455.01	357949.2
Source wise energy (MJ/ha)											
Human	15842.46	13007.54	15085.79	15461.46	14974.89	27220.97	15062.6	14633.36	13025.98	12267.64	15658.25
Animal	-	1212	-	-	-	-	1818	-	453	-	348.3
Diesel	49885.02	39440.65	32379.36	26163.86	23153.53	27975.36	22447.41	77413.29	41810.16	23822.49	36449.1
Electricity	300367.5	253292.4	233619	233619	216930	233619	200244.9	250306.2	166870.8	166870.8	225573.96
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125	37497.50
Fertilizer	61200	25245	30045	29454	30369	61200	34731	35877	23485.5	23485.5	35509.2
FYM	1800	-	-	900	-	1350	-	1350	-	-	540.00
Chemical	1614	-	450	540	909	1080	450	1080	-	-	612.30
Machinery	9048.64	6088.32	5268.51	4540.5	4205.91	4615.08	5016.87	8485.8	7150.53	3736.77	5597.11
Total	482157.62	374723.41	353285.16	347778.82	330292.33	396810.41	316870.78	428895.65	285920.97	263308.2	357785.72
Grand total	962318.8	749641.6	706726.01	695704.45	660740.85	793750.23	633935.62	857920.13	571996.83	526763.21	715734.92
Yield q/ha 2013-16	3575	2700	2250	2400	2375	3000	2325	3075	1875	2175	2575
Energy ratio	1.96	1.90	1.68	1.82	1.90	2.00	1.94	1.89	1.73	2.18	1.90
Specific energy MJ/ kg	2.69	2.77	3.14	2.89	2.78	2.64	2.72	2.78	3.05	2.42	2.77
Productivity kg/MJ	0.37	0.36	0.31	0.34	0.35	0.37	0.36	0.35	0.32	0.41	0.35

Appendix 10

Energy from different classified sources and determination of energy coefficients in Narsinghpur 2013-16:

Energy (MJ/ha)	Survey years (2013-16)
Direct energy	278029.61
Indirect energy	76756.11
Renewable energy	51044.05
Non renewable energy	303741.67
Direct renewable energy	16006.65
Direct non-renewable energy	262023.06
Indirect renewable energy	35037.5
Indirect non-renewable energy	41718.61
Commercial energy	303741.67
Non-commercial energy	16546.55
Direct-indirect energy ratio	3.62
Renewable – non-renewable energy ratio	0.16
Direct renewable-direct non renewable energy ratio	0.06
Indirect renewable-indirect non renewable energy ratio	0.89
commercial –non-commercial energy ratio	18.35
Productivity (kg/MJ)	0.35
Yield (q/ha)	2575
Specific energy (MJ/kg)	2.77
Output-input energy ratio (MJ/unit)	6.86

CURRICULUM VITAE

The author of this thesis Avinash Kumar was born on 08/08/1993 at Malihabad Block of Lucknow District (Uttar Pradesh). He passed his High School (10th) in the year of 2009 and Higher Secondary in the year of 2011 from Government Jubilee Inter College Lucknow (Uttar Pradesh).

In 2011 he joined the Sir Chhotu Ram Institute of Engineering and Technology campus of Chaudhary Charan Singh University, Meerut, (Uttar Pradesh).

He has successfully completed B.Tech. (Agricultural Engineering) degree in the year of 2015 with 7.39 OGPA out of 10.00 point scale. After graduation he joined M.Tech. (Agricultural Engineering) to specialize in Farm machinery and power Engineering in College of Agricultural Engineering, JNKVV, Jabalpur (Madhya Pradesh). He has completed his course work.

For the partial fulfillment of Master's Degree, he was allotted need based research problem entitled **"Energetics of Sugarcane in the district of Narsinghpur, Madhya Pradesh"** which was duly completed by him and presented in the form of this thesis.